SYLLABUS

OF

Lectures on Physiology

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Dedicated

TO

MY STUDENTS

PAST, PRESENT, AND FUTURE.

PREFACE.

I know that many objections are raised to the use, by students, of compends and digests, but I do not consider them valid, therefore I do not share them, and therefore I have not hesitated to add another to the list of objectionable books.

Even in a medical course of four years, with days of twenty-four hours, it is physically impossible for students to keep pace with the lectures by study of voluminous text-books.

They study Physiology, not to become scientists, but to get a necessary foundation for their future medical studies.

My own views, arrived at after many years of teaching, are that the lectures should seek to cover the ground as thoroughly as possible, presenting all that is best and most practical in the various text-books, and that the student should be furnished with a guide by which he can, with the least expenditure of time and energy review the subject, and fix in his memory its salient points, in a form most easily recalled.

I have sought to provide such a guide in this Syllabus of my lectures on Physiology.

I have endeavored to appeal to his visual memory wherever possible, and, with an entire and willing sacrifice of every attempt at literary elegance, have tried to present the facts in a form most easily grasped, most readily memorized, and most quickly recalled.

The book will readily lend itself to the use of the quiz-master, and in the system of recitations, which I intend connecting with my course in Physiology in future, it will, I am sure, be of assistance to me as well as to my students.

The book can lay no claim to originality, only to individuality.

I have not hesitated to borrow, at times *verbatim et literatim*, from the best and latest authorities, and to them all I now, *en gros*, without invidious distinction, present my acknowledgments.

With the hope that the book may prove acceptable to a wider circle than that of my own immediate students, I shall however be content if the latter receive all the good from it that was intended in its preparation.

W. H. B.

September 1, 1898.

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PHYSIOLOGY.

INTRODUCTION.

Physiology is the doctrine of Life, or of the vital phenomena of plants and animals. (Vegetable and Animal Physiology.)

Human Physiology is the science treating of the functions of the human body in a state of health (*vs.* Pathology).

Function = the characteristic work of an organ.

Organ is a tissue, or collection of tissues (= a structure), intended to perform a certain work.

The science which teaches the gross structure of organized bodies is Anatomy.

The science which treats of the microscopic structure of the tissues which compose the organs is Histology.

A knowledge of the chemical composition of the human body is given us in Chemistry.

(Comparative Anatomy, Pathology, Physics, Embryology—Vivisection—as auxiliary to the study of Physiology.)

PART I.—STRUCTURAL COMPOSITION OF THE BODY.

The human body with its dissimilar structures has originated from a single minnte cell, the ovum.

(Schleiden, Schwann. Vegetable and animal cells.)

A cell is a mass of protoplasm, capable of manifesting the phenomena of life.

(Unicellular organisms.)

Protoplasm is an unstable albuminoid substance, semi-fluid, viscid, semi-transparent, neutral or faintly alkaline, or even acid under certain circumstances. Under the microscope shows a granular appearance.

The Vital Phenomena manifested by protoplasm are:

Power of spontaneous movement;

Irritability, or response to stimuli, thermal, mechanical, chemical, electrical, and nervous;

Nutritive powers, and growth . metabolism ; assimilation, anabolism ; dissimilation, katabolism ;

Reproductive power : Gemmation, Fission or Division. Amœbæ and Amœboid movements.)

Protoplasmic Cells, consist of two parts, a net-work or reticulum of fibrils, and a more fluid part contained within its interstices : (protoplasma, reticulum, or spongiosum, and para-plasma, enchylema, or hyaloplasma).

The younger the cell the more abundant the fluid part. Uncertain which is the essential part.

Nearly all cells possess at some time a nucleus, and often a nucleolus.

The Division of the Cell is initiated by the division of the nucleus, or of a special structure, the centrosome (chromatin).

Either simple or direct, or. indirect, called karyokinesis (a kernel) or mitotic (a thread).

(Differences between animals and plants.)

The original spherical cell in the human body, called the ovum, is formed, by division into a complete membrane of cells (polehydral in shape, from mutual pressure called the **Blastoderm.**

This speedily divides into two, the epi-blast and the hypo-blast, and from these a third, the meso-blast, is formed.

From these are then formed all the various tissues of the body, which may be classified as follows :

(1) The Epithelial,
(2) The Connective,
(3) The Muscular,
(4) The Nervous,
(5) Blood and Lymph. (*Vide* Development.)

PART II.—THE CHEMICAL COMPOSITION OF THE BODY.

Seventeen of the sixty-five chemical elements combine in larger or smaller quantities to form the chemical basis of the body.

The non-metallic elements, Oxygen, Carbon, Hydrogen, and Nitrogen, contribute the largest share, while of the metallic elements the most abundant are Calcium, Sodium and Potassium.

The only elements found free in the body are O, N, and H ; all in the intestinal canal, and the first two in the blood also.

The term "organic" is now applied only to the compounds of C.

[**Organic Chemical Substances.** (The following section is intended to give the student a few points of departure from which he may be aided in bringing to bear upon physiological chemistry what he learns from the chair of organic chemistry.)

Hydrocarbons are compounds of C and H; C being a tetrad element (C_{iv}), the simplest hydrocarbon is CH_4 methane or marsh gas, found in the intestines, 25 to 50 per cent.; the only hydrocarbon found in the body.

It is the first of the series known as paraffins.

By substituting OH (hydroxyl) for H we obtain from a hydrocarbon the corresponding alcohol, which may also be regarded as a hydrate of the hydrocarbon, constructed on the water type *i. e.* as a molecule of water, in which one of the H atoms has been replaced by a hydrocarbon radicle.

Alcohols may be classified as mon-atomic, di-atomic, etc., according to the number of OH groups in the molecule.

Ethers are obtained by the dehydration of their corresponding alcohols. (Ethyl ether—sulphuric ether—æther (U. S. P.)).

Aldehydes are obtained by the oxidation of the alcohols.

Acids are obtained by further oxidation, one atom of O being substituted for H_2, *e. g.* acetic acid, formic acid.

The series of acids obtained from the first series of paraffins is known as *fatty acids*. The most familiar are butyric, caproic, palmitic, stearic.

The first series of hydrocarbons, the paraffins, consist of saturated hydrocarbons, but others exist, in which the C is unsaturated, *e. g.* olefines, acetyline, etc.

From each series of hydrocarbons, the corresponding alcohols, ethers, aldehydes, and acids are formed.

In the olefine series, from ethene, C_2H_4, the alcohols are called glycols, glocolic acid; oxalic acid.

Cholesterine is a mon-atomic alcohol.

From propene we have lactic acid; malonic acid.

Glycerine is a tri-atomic alcohol;—an hex-atomic alcohol is mannite, from which the carbohydrates are derived.

Of the aldehydes, acetone is found in blood and in urine, particularly in diabetes.

The glucoses are aldehydes of mannite, and the other carbohydrates are derived from that class.

Of the benzine or aromatic hydrocarbons, benzoic acid is found in stale urine, and phenol or carbolic acid in minute quantities in urine.

Amido-acids may be regarded as acids in which one or more of the H atoms of the acid radicle are replaced by amidogen, NH_2.

Most important are :—

glycin,	sarcosine,	taurine,	urea,	hypoxanthin,
leucine,	kreatine,	cystine,	uric acid,	allantoin,
tyrosine	kreatinine,	hippuric acid,	xanthin,	etc.]

The various substances found in the body can be classified in general, as

I. ORGANIC, (a) **Nitrogenous,** (b) **Non-nitrogenous.**

II. INORGANIC.

Enumeration of the chief chemical ingredients found in the tissues. (Adapted from Yeo.)

I. Proteids. Highly complex bodies made by assimilation and required for animal metabolism, often containing S, P, and Fe in addition to C, H, N, and O.

Albumins :
- serum-albumin,
- egg-albumin,
- myo-albumin,
- lact-albumin.

Globulins :
- fibrinogen,
- serum (para-) globulin,
- myosinogen,
- globin, from hæmoglobin,
- crystallin, from the crystalline lens.

Albuminates, or Derived Albumins :
- acid-albumin, or syntonin,
- alkali-albumin.

Proteoses :
- albumoses ;
  - hemi-albumoses,
  - anti-albumoses,
    - primary albumoses, or proteoses=
      - proto-proteose,
      - hetero-proteose,
      - deutero-albumoses,
- globulinoses,
- myosinoses.

Peptones:

hemi peptone, from hemi-albumose, yielding leucin and tyrosin in tyrptic proteolysis;

anti-peptone, from anti-albumose, not yielding leucin and tyrosin.

Coagulated proteids:

fibrin,

casein, (classed also as a nucleo albumin, or a nucleo-proteid),

myosin.

Hæmoglobin, (classed as a combined proteid, a proteid with an iron pigment).

II. Albuminoids:

mucin, (classed also as a combined proteid, a glyco-proteid, a proteid with a carbohydrate),

gelatin,

chondrin,

elastin,

keratin, and nucleo-keratin,

nuclein,

nucleo-albumin.

III. Products of Tissue Changes:

glycin, glycocine or amido-acetic acid;

sarcosine, or methyl-glycocine, (in kreatin);

urea or carbamid, ($(NH_2)_2CO$);

leucin, (amido-caproic acid) and

tyrosin, (amido-oxy-phenyl-propionic acid);

taurin, (amido-ethyl sulphonic acid);

cholic acid;

glycocholic acid;

taurocholic acid;

hippuric acid, or benzamidacetic acid;

kreatin, losing a molecule of H_2O, becomes

kreatinin;

uric acid, (or lithic acid);

indol, } from proteid putrefaction;

skatol,

cholin, (one of the ptomaïnes, in putrifying animal matters; also in lecithin);

neurin, (also a ptomaïne, closely related to cholin);

lecithin, (containing P, and, with cerebrin, forming protagon in the brain, found alone also in nerves);
cholesterine, (a monatomic alcohol);
inosite, (long mistaken for a carbohydrate; origin unknown).

IV. Pigments and Ferments may be added to these as nitrogenous substances.

Pigments:

bilirubin, biliverdin, bilifuscin, biliprasin, bilihumin (*vide* Bile);
urochrome, urobilin, uroerythrin (*vide* Urine);
stercobilin;
melanin;
indican, and indigo;
hæmatin (*vide* Blood).

Ferments (*vide* Digestion).

V. Carbohydrates:

I. Glucoses,—$C_{12}H_{24}O_{12}—H_2O=$

dextrose,
levulose,
galactose.

II. Saccharoses,—$C_{12}H_{22}O_{11}—H_2O=$

sucrose,
maltose,
lactose.

III. Amyloses,—$C_{12}H_{20}O_{10}$

starch,
dextrin,
glycogen.

VI. Fats.

stearin,
palmitin,
olein; formed from the combination of
fatty acids with glycerine.

VII. Inorganic Substances.

O—H—C—N.
H_2O, forms about 70 per cent. of the body.
Acids; Bases; Salts.
acids: HCl; carbonic; phosphoric; sulphuric; hydrofluoric; silicic.
bases: sodium; potassium; ammonium; calcium; magnesium.

Some General Reactions of the Proteids.

Soluble in water: Native albumins, peptones.

Insoluble in water: Derived albumins, globulins, fibrin.

Soluble in saline solutions: Globulins, fibrin, peptones.

Insoluble in saline solutions: Derived albumins, fibrins (in dilute solutions).

Soluble in acids and alkalies: Derived albumins, globulins (in dilute solutions); fibrin, peptones.

Insoluble in acids and alkalies: Fibrin, (in dilute solutions).

Coagulated by heat: Native albumin, globulin.

Non-coagulable by heat: Derived albumins, peptones.

Chemical reactions of the Proteids.

I. Xantho-proteic reaction. A solution of any proteid boiled with strong nitric acid becomes yellow, and the cooled solution is darkened by the addition of ammonia. In some cases the acid throws down a white coagulum, which speedily becomes yellow on boiling.

II. Biuret reaction. With a trace of copper sulphate and an excess of K or Na hydrate, they give a purple or rose-red coloration.

III. Millon's reaction. With Millon's reagent, (a solution of metallic Hg in strong nitric acid), they give a white or pinkish clotted precipitate, becoming more pink or red on boiling.

IV. Ammonium sulphate reaction. They are, with the exception of peptone, entirely precipitated from their solutions by saturation with ammonium sulphate. Many, in addition, show the following:

V. With excess of acetic acid and *potassium ferrocyanide* throw down a white precipitate.

VI. With excess of acetic acid and a saturated solution of sodium sulphate, on boiling, give a white precipitate.

VII. Boiled with strong hydrochloric acid, take on a violet-red coloration.

VIII. With cane sugar and strong sulphuric acid, give, on boiling, a purplish coloration.

IX. Are precipitated on addition of citric or acetic acid, and picric acid; or citric or acetic acid with sodium tungstate; or citric or acetic acid with potassio-mercuric iodide, etc.

(*Cf.* Tests for Albumin in the Urine.)

Chemical Reactions of the Carbohydrates.

A *solution of starch* is colored blue by the addition of iodine. The color disappears on heating, but reappears on cooling.

Tests for the Glucoses.

I. Trommer's, depends upon the power possessed by glucose to reduce copper salts to their sub-oxides.

An excess of caustic potash and then a solution of copper sulphate, drop by drop, are added to the solution containing sugar in a test tube,—as long as the blue precipitate which forms redissolves on shaking. The upper portion of the fluid is then heated, and a yellowish-brown precipitate of copper suboxide appears. Only a drop or two of the copper solution may be used.

II. Fermentation. If a solution of sugar be kept in a warm place for a time after the addition of yeast, the sugar is converted into alcohol and carbon-dioxide. Quantitative test of sugar in urine; Take sp. gr. of urine before and after fermentation. Each degree of sp. gr. lost by the urine represents one grain of sugar per ounce of urine; or, collect and measure amount of carbon-dioxide evolved. (Saccharimeter, Einhorn's.)

III. Fehling's. Fehling's solution — sulphate of copper 40 grms.; neutral tartrate of potash, 160 grms.; caustic soda (sp. gr. 1.12,) 750 grms.; distilled water to 1154.5 c.c.:—each 10 c.c. will reduce .05 grm. of sugar.

Can be used therefore for the quantitative estimation also.

The solution must be freshly prepared, if on boiling alone it becomes yellow.

IV. Haine's solution is permanent. (30 grs. sulphate of copper, ½ oz. distilled water, to which ½ oz. of glycerine is added, and the whole mixed with 5 oz. of liquor potassæ.

A drachm is gently boiled, and the urine is added drop by drop, until 6 to 8 drops have been added, but no more. If sugar is present, a copious yellow or yellowish-red precipitate of the usual anhydrous suboxide of copper is thrown down.

Of the saccharoses, sucrose or cane sugar does not reduce copper salts.

Other tests may be used, as Boettger's (bismuth oxide or subnitrate, and liquor potassæ).

Phenyl-hydrazine; Moore's; etc.

(*Cf.* Tests of Sugar in the Urine.)

Chemical Reactions of Products of Tissue Changes.

Urea, or Carbamid $(NH_2)_2CO$.—Quantitative estimation in urine.

I. Liebig's Method, with (a) baryta mixture; (b) a standard solution of mercuric nitrate; (c) a solution of carbonate of soda.

II. Hypobromite method. The most convenient apparatus is Doremus's ureometer, with the following hypobromite solution: a solution of sodium hydrate of the strength of 1 oz. to one pint of distilled water is made. Of this ten volumes are added to one volume of bromine, and diluted with ten volumes of water.

The solution is not stable, and should therefore be prepared in small quantities at one time.

Chemical Reactions of Inorganic Substances.

Quantitative estimation of Chlorides. Liebig's method requires baryta mixture = 2 vols. of saturated solution of barium nitrate and 1 vol. of barium hydrate; (b) a standard solution of mercuric nitrate, such that 1 c. c. is capable of decomposing .01 grm. of sodium chloride.

Simplest approximate test: add a few drops of nitric acid, then gradually introduce, drop by drop, a solution of nitrate of silver (1 to 8). The quantity to be judged by amount of chloride of silver formed.

Quantitative estimation of Phosphates. Solutions required are (a) a solution of sodium acetate, containing 100 grms. of sodium acetate, 100 c. c. of acetic acid, and 900 c. c. of distilled water; (b) a solution of uranium acetate or nitrate, such that 1 c. c. will precipitate .005 grm. of phosphoric acid; and (c) a solution of ferrocyanide of potassium.

SECTION I.

FOOD.

All activity, vital or otherwise, implies waste of material.

This loss must be made up by assimilation, from without, of materials which constitute food.

The purpose of food is, therefore, to supply new tissue, ether for growth or for replacing body waste. Besides this it is necessary for the production of heat and the evolution of energy.

Food-stuffs exist, in most cases, in a form, and with a composition differing widely from that of the tissues of which they are to form a part.

The object of the processes of digestion is to change these food-stuffs so that they may be utilized by the tissues of the body.

(Plants use simple inorganic food-stuffs, from which they manufacture complex combustible materials, organic, as food-stuffs for animals. They use up CO_2 and set free O, which animal protoplasm demands for its oxidation).

CHAPTER I.

On analysis the various animal and vegetable food-stuffs made use of by mankind, are found to contain in varying proportions, one or more of the following alimentary substances:

I. **ORGANIC:**

(a) **Nitrogenous.**
- *Proteids* or proteid-containing bodies;
- *Albuminoids*, (bodies resembling proteids but having a different nutritive value).

(b) **Non-nitrogenous:**
- *Carbohydrates;*
- *Fats.*

II. **INORGANIC:** Water, and inorganic salts;

The nutritive value of any food depends upon:

I. Chemical composition:

I. The proportion of soluble and digestible matters to those which are insoluble and indigestible;

II. The number of different kinds of nutrient stuffs present;

III. The relative proportion of each of the chemical groups.

II. Mechanical construction ;

I. The degree of sub-division when introduced into the stomach ;

II. The relation of the nutritive to the non-nutritive.

III. Digestibility ;

IV. Individual idiosyncrasy.

ORGANIC FOODS.

Organic nitrogenous foods:

Flesh of animals, including beef, veal, mutton, pork, venison, game, poultry, fish.

Milk,

Leguminous fruits, eggs.

Organic non-nitrogenous foods.

I. Carbohydrates, including bread, vegetables, fruits, sugar.

II. Oils and fats, including butter, lard, suet, and vegetable oils.

INORGANIC FOODS.

I. Salts. Found in nearly all the foregoing substances ; absolutely necessary to the body.

NaCl is an essential food.

Potassium salts are supplied in muscle, nerve, in meats generally, and in potatoes.

Calcium salts in eggs, blood of meats, wheat, and vegetables.

Iron in hæmoglobin, in milk, eggs, and vegetables.

II. Water, either alone or in combination, *e. g.* with tea, coffee, cocoa, beer, cider, wine, spirits.

(Effects of tea, coffee, and alcohol.)

Effects of Cooking upon meat, eggs, milk, vegetables, flour, as dough, in baking.

Hunger and Thirst.

STARVATION: Symptoms and post-mortem appearances.

PROLONGED FASTING: (Succi.-Jacques.)

CHAPTER II.—QUANTITY AND QUALITY OF FOOD.

Life may be sustained either on an animal or a vegetable diet, digestion converting albumin into albuminose, whether derived from vegetable or animal substances, and assimilating the fats and salts, no matter what their source.

The character of man's teeth and of his alimentary canal show that he was intended to be an omniverous animal.

The disadvantages of a purely vegetable diet are:

I. Low proteid quantity;

II. Reduction of fats and increase of sugar.

III. Large amount of undigested material to be gotten rid of as fæces, at the expense of energy.

IV. An excess of mineral salts.

Both quality and quantity of food should vary with the climate and season, and occupation.

A study of the healthy excreta shows that the proportion of N to C should be as 1 to 15 ($N1 : C15$).—Nitrogenous equilibrium.

To keep these proportions, a mixed diet is necessary, in which the nitrogenous foods shall be to the non-nitrogenous as 1 to 3½–4½. (These figures refer to dry material.)

Any one in active work requires more food than one at rest; children and women require less than adult men.

Experience has shown that proteids in certain articles of food can be digested and absorbed nearly completely when not fed in excess, while in other foods only a certain percentage of the proteid is absorbed under the most favorable circumstances.

In general it may be said, that in meats from 2 to 3 per cent., in milk from 6 to 12 per cent., and in vegetables from 10 to 40 per cent. of the proteid escapes absorption.

COMPOSITION OF FOODS. (By Monk from Koenig.)

In 100 parts.	Water.	Proteid.	Fat.	Carbohydrates. Digestible.	Carbohydrates. Cellulose.
Meat	76.7	20.8	1.5	0.3	
Eggs	73.7	12.6	12.1	. .	
Cheese	36–60	25–33	7–30	3–7	
Cow's milk	87.7	3.4	3.2	4.8	
Human milk	89.7	2.0	3.1	5.0	. .
Wheat flour	13.3	10.2	0.9	74.8	0.3
Wheat bread	35.6	7.1	0.2	55.5	0.3
Rye flour	13.7	11.5	2.1	69.7	1.6
Rye bread	42.3	6.1	0.4	49.2	0.5
Rice	13.1	7.0	0.9	77.4	0.6
Corn	13.1	9.9	4.6	68.4	2.5
Macaroni	10.1	9.0	0.3	79.0	0.3
Peas, beans, lentils	12–15	23–26	1½–2	49–54	4.7
Potatoes	75.5	2.0	0.2	20.6	0.7
Carrots	87.1	1.0	0.2	20.6	0.7
Cabbages	90.	2.3	0.5	4.6	1–2
Mushrooms	73–91	4.8	0.5	3–12	1–5
Fruit	84.	0.5	. .	10.	4.

Any single article of food, if taken in sufficient quantities to supply the necessary N, will give too much or too little C; and the reverse; those animal foods which, in certain amounts, supply the N needed, furnish only from one-quarter to two-thirds of the necessary amount of C.

For 110 grms. proteid. (Monk.)

(17.5 grams N.)		For 270 grams C.
Milk	2900 grams	3800 grams
Meat (lean)	540 "	2000 "
Hen's eggs	18 eggs	37 eggs
Wheat flour	800 grams	670 grams
Wheat bread	1650 "	1000 "
Rye bread	1900 "	1100 "
Rice	1870 "	750 "
Corn	990 "	660 "
Peas	520 "	750 "
Potatoes	4500 "	2550 "

In this table it is supposed that the daily diet should contain 110 grams proteid = 17.5 grams of N, and non-proteids sufficient to contain 270 grams of C.

Potential energy of food. Isodynamic equivalents. Fats and carbohydrates serve to supply energy; weight for weight fat contains most energy, but its use limited.

Dietetics: for different ages; in various diseases; for collections of individuals, in armies, hospitals, asylums, prisons, etc. (*Vide* works on Hygiene, etc.)

Average amount of food required daily: 16 oz. meat, 19 oz. bread, 3½ oz. fat, 52 oz. water.

Nutritive importance of the proteids.

N is absolutely necessary to the formation of new protoplasmic material in the form of proteids (in albumin).

Nitrogenous equilibrium cannot be maintained on a diet of carbohydrates and fats, even if N be added in the form of albuminoids, *e. g.* gelatine.

But albuminoid food can take the place of the circulating proteid, so that only enough proteid need be given to supply the actual tissue waste.

An excess (formerly called "luxus consumption" of proteid, over the amount necessary to repair waste, is found to be required in order that the tissues may preserve their nutritional and metabolic powers in a condition of normal activity.

This beneficial excess has a limit; too great an excess of albuminous food promotes the arthritic diathesis, manifesting itself as gout, gravel, etc., through the imperfect combustion of the urates.

Nutritive value of the albuminoids.

That one most frequently occurring in our food is gelatine. Derived from collagen of the connective tissue. This (from bones and connective tissue) when boiled takes up water and is converted into gelatine. Found therefore in boiled meats, soup, etc.

Its use to the exclusion of albumin results in malnutrition and death, with an excess of N in the urine from broken down tissue. It is, however, readily digested (gelatoses; gelatine-proteoses), absorbed and oxidized, with formation of CO_2, H_2O, and urea, with liberation of energy, the same as carbohydrates and fat. It is burned in place of the proteïd. Has the same nutritive value, but cannot be constructed into living protoplasm.

Nutritive value of fats. The fats of food eventually reach the blood as neutral fats, and are in some way consumed in the tissues, with the formation of CO_2, H_2O, and the liberation of energy.

Contain, weight for weight, more available energy than the proteids and carbohydrates, and therein lies their essential nutritive value.

The body-fat is a reserve supply of nourishment, drawn upon whenever the diet is insufficient to cover the oxidations in the body.

Nutritive value of the carbohydrates. Similar in general to that of the fats. Oxidized to furnish energy with CO_2 and H_2O as final products.

May be converted into fat to form a reserve supply of nourishment.

Financially the cheapest food-stuff.

Excess of oleaginous diet produces a bilious diathesis; a deficiency seems to favor the so-called scrofulous diathesis.

(Use of cod-liver oil, butter, cream, in scrofulous and rachitic conditions.)

Excess of carbohydrates favors an accumulation of fat (obesity), which may interfere with the nutrition of the muscles, causing weak heart, etc.

Too much starch gives rise to acid dyspepsia and flatulence.

Excess of sugar and starch may give rise to glycosuria.

Rheumatism is thought by some to be due to the acidity resulting from starches and sugars of vegetables, by development of lactic acid.

Deficiency of these may cause scurvy.

Nutritive value of water and salts.

Neither serve as sources of energy.

The water taken in as food, and that formed in the body, is necessary to normal metabolism, but is eliminated in the form in which it is taken in, by the kidneys, skin, lungs, and in the fæces.

Of the inorganic salts, some are eliminated in the form in which they are taken; others are formed in the body, especially the sulphates and phosphates. Their chief value lies in the fact that they are essential to the normal physical and chemical properties of the tissues and fluids of the body. The proteids in nature are always in combination with inorganic salts. The Ca salts are necessary to bone and to the coagulation of blood, and in some way connected with the rhythmical contraction of the heart-muscle, and with the normal activity of protoplasm in animals as well as in plants.

The importance of the iron salts lies in their relation to hæmoglobin. In animal and vegetable foods iron is contained in the form of an organic compound, and only when so combined can iron be absorbed readily, and utilized by the body.

Origin of fat in the body.

Very little of the fat of the food is deposited as fat in the tissues; it is nearly entirely oxidized; and our body fat is normally constructed anew from the proteids and carbohydrates.

According to Voit the proteid molecule splits into a nitrogenous and a non-nitrogenous part. The former leaves the body, after undergoing various changes, as urea, completely oxidized; the latter may be converted into fat, or possibly glycogen.

The carbohydrates form one source, possibly the main source of the body fat.

Corpulence. Conditions favoring corpulence. Obesity.

(Banting. Oertel. Anti-fats.)

SECTION II.

DIGESTION.

Introduction.

Digestion includes the physical and chemical processes by which the food-stuffs taken into the body are put into a condition in which their nutritive principles are transformed into new substances, capable of being absorbed into the blood. May be divided into seven stages:

Prehension,
Mastication,
Insalivation,
Deglutition,
Gastric and Intestinal digestion,
Defæcation.

The digestive apparatus consists of the Alimentary Canal, and its Appendages, viz., Teeth,
Salvary glands,
Gastric and Intestinal glands,
Liver,
Pancreas.

(Comparative Anatomy and Physiology of the Digestive Tract.)

ENZYMES. The chemical changes which the various food-stuffs undergo throughout the digestive tract are the result of the activity of certain bodies known as *enzymes.*

Enzymes are unorganized ferments, a group of bodies found in animals and plants, not themselves endowed with the structure of living matter; hence distinguished from these bodies, and from living ferments, such as the yeast plant, or bacteria.

Chemically, they are complex organic compounds containing N, but their exact composition is unknown.

Classification:

Proteolytic: *e. g. pepsin, trypsin,* and in the pineapple, bromatin, and in the papaw, papain.

Amylolytic: *e. g. ptyalin, amylopsin,* and in the liver one to convert glycogen into sugar. In plants, *diastase,* found in germinating plants, (used in the manufacture of beer). This name is often applied to the whole class of starch-destroying ferments.

Fat-splitting enzymes: acting upon the neutral fats, breaking them up into glycerine and the corresponding fatty acid. The best known is the *steapsin* of the pancreatic juice. Similar enzymes are found in a number of seeds.

Inverting enzymes: converting or inverting the double into the single sugars, the di-saccharides into the mono-saccharides, *i.e.*, cane sugar and maltose, into dextrose and levulose. Two such are found in the animal body; one acting upon the former, the other upon the latter. Usually spoken of as *invertin*. Similar enzymes can also be derived from the yeast plant.

Coagulating enzymes: acting upon soluble proteids, precipitating them in an insoluble form: *e. g. fibrin ferment*, thrombin(?) in shed blood, and *rennin*, the milk-curdling ferment of the gastric juice. A ferment similar to rennin is found in pineapple juice.

These five are found in the animal body; two others are here mentioned for sake of completeness:

Glucoside-splitting enzyme: acting upon glucosides, giving a carbohydrate as one of the products of decomposition: *e. g.* emulsin, in bitter almonds; myrosin, in mustard seeds.

Urea-splitting enzymes: acting upon urea, converting it into ammonia carbonate, found in many bacteria, especially those normally occurring in urine.

General reactions of Enzymes. Among the most useful and significant are the following:

I. Solubility. All are soluble in water and in glycerine, this latter being the most generally useful solvent for obtaining extracts of the enzymes from the organs in which they are formed.

II. Effect of Temperature. In a moist condition all are destroyed by a temperature somewhat below boiling point; 140° to 176° F. (60° to 80° C.) are the limits observed. Very low temperature (0,C.) retards or entirely suspends their activity, without destroying them. For each enzyme there is an optimum temperature at which their action is greatest.

III. Incompleteness of action. With the exception perhaps of the coagulating enzymes, they never completely destroy the substance upon which they act. Accumulation of the products of their activity

prevents further action; removal of them allows the enzymes to resume their activity.

IV. Relation of the amount of enzyme to the effect produced. The amount of change produced by them is independent of the amount in which they are present, although their activity is not unlimited, as held by some.

(Theories of the manner of action of the enzymes.)

CHAPTER I.—PREHENSION.

MOUTH; mucous membrane; glands.

TONGUE, muscles, intrinsic and extrinsic.

Papillæ; circumvallate, fungiform, and filiform (gustatory cells; taste goblets).

Nerves of taste: chorda tympani, gustatory and glosso-pharyngeal, through their connection with the 5th or trigeminus. (*vide* Taste.)

Motor nerve, the hypoglossal.

TEETH. In man partake of the character both of carniverous and herbiverous.

Structure; crown, covered by enamel (Nasmyth's membrane); a neck and root, surrounded by the crusta petrosa; with the body of dentine, containing the pulp cavity.

Temporary set 20; permanent set 32.

Time of eruption of temporary set, in months:

24	12	18	9	7	|	7	9	18	12	24

Time of eruption of permanent set, in years:

17 to 25	12 to 13	6	9	10	11	8	7	|	7	8	11	10	9	6	12 to 13	17 to 25

Formation of the teeth.

The development of the temporary teeth is said to commence about the sixth week of intra-uterine life, after the laying down of the bony structure of the jaw. Their permanent successors begin to form about the sixteenth week of fœtal life. A thickened portion of the deeper layer of stratified epithelium of the mucous membrane of

the mouth, in the position of the forming jaw, passes downward as the *primary* or *common enamel germ*, leaving the *enamel groove* in the mucous membrane of the mouth.

An increased development, at certain points corresponding to the situation of the future milk-teeth, takes place, and the common enamel germ becomes divided at its deeper portion into a number of special enamel germs, corresponding to each of the teeth, connected to the common germ by a narrow neck, but each placed in its own special recess in the embryonic jaw.

From below there grows up into each enamel germ a distinct vascular papilla, and upon it the enamel germ becomes moulded, and presents the appearance of a cap of two layers of epithelium separated by an interval.

Of the subepithelial tissue, therefore, the one part forms the papillæ, and the other encloses the embryonic teeth as the dental sacs, while the bony gutter in which the germs lie sends up partitions between them.

The outer part of the papillæ is covered by a layer of columnar nucleated cells, called *odontoblasts*. These become elongated and calcified, forming the dentine. (Exact manner not determined.)

As the dentine increases the papilla diminishes, until only a small amount remains, as dental pulp, supplied by vessels and nerves which enter at the end of the root; the number of roots being foreshadowed by the number of arteries going to the papilla.

The enamel is formed in connection with the dentine; the cement or crusta petrosa from the internal tissue of the tooth sac; while the outer layer of the membrane of the tooth-sac forms the fibrous dental periosteum. The periosteum is a means of attachment of the tooth to its socket, and, with the pulp, a source of nourishment. (Exostosis. Absorption of the root.) The first set of teeth, in developing, press upward on the walls of the enclosing sacs, and are successively "cut."

Each temporary tooth is replaced by a tooth of the permanent set which is developed from a small sac, set by as "the reserve cavity" from the sac of the temporary tooth which precedes it. The permanent tooth, pressing up, absorbs the whole of the root of the milk tooth above, until there is a mere shell left to be shed to make way for its eruption.

(Abnormal development of teeth. Decay. Influence of disease and drugs. Rachitis. Gout.)

CHAPTER II.—MASTICATION.

Entirely voluntary. Purpose.

MUSCLES. The temporal, masseter, and internal pterygoid, raise the jaw; the digastric, mylo-hyoid and genio hyoid, depress it; the external pterygoids produce the grinding movements.

NERVES. Nerve centre in the medulla.

Afferent nerves, the sensory branches of the 5th and the 10th (glossopharyngeal);

Efferent nerves, the motor branches of the 5th (inferior maxillary), and the 12th or hypoglossal.

CHAPTER III.—INSALIVATION.

SALIVARY GLANDS; parotid, (with Steno's duct), sub-maxillary and sub-lingual (with ducts of Wharton, of Rivinus, and of Bartolini). They are racemose glands, with acini, the terminal expansions of the smallest salivary ducts.

SECRETION OF SALIVA. *Nervous mechanism*: Centre in the medulla.

Afferent nerves, the gustatory or lingual branch of the inferior maxillary of the 5th, and the glosso-pharyngeal:

Efferent nerves, the chorda tympani, for the sub-maxillary and sub-lingual; and the auriculo-temporal of the 5th for the parotid and sympathetic fibres for all.

SALIVA. Of the parotid, thin; of the sub-maxillary and sub lingual, thick and viscid.

Mixed saliva is an opalescent, slightly viscid, at first alkaline then neutral, fluid; sp. gr. 1005.

Quantity about 3 pints in 24 hours (300 to 1500 grams).

In infants very little, until after the sixth month.

Microscopically it shows epithelial cells from the mouth, and "salivary corpuscles," which are probably altered leucocytes.

Chemically it contains, in addition to water, mucin, ptyalin, albumin, and inorganic salts (potassium sulpho-cyanide in traces, chlorides and phosphates; sodium chloride and phosphate, and calcium and magnesium phosphates).

(Abnormal constituents: lactic acid in diabetes; ingested drugs excreted; various micro-organisms.)

Functions. *Physical :* moistens and lubricates the parts ; dissolves soluble food ; lubricates the bolus.

Chemical : converts starch into maltose through the intermediate erythro-dextrine, and achroodextrine, by means of the amylolytic enzyme, ptyalin.

(Starch is converted into dextrose by boiling with dilute mineral acids).

(Tests for starch and sugar, *vide* Chemical Introduction).

Conditions influencing the action of ptyalin : temperature, chemical reaction (exactly neutral the best), and condition of the starch. The addition of NaCl increases the action. Tea inhibits salivary digestion, while coffee and cocoa have but little effect.

(Chorda saliva. Paralytic saliva. Ptyalism. Sialagogues. Antisialics. Excretion of certain drugs through the saliva.

CHAPTER IV.—DEGLUTITION.

Fauces ; pharynx ; tonsils ; œsophagus.

Act of deglutition : mouth is closed, by action of the tongue ; the bolus of food is pressed behind the anterior palatine arch into the pharynx ; the pharyngo-nasal cavity is shut off by the approximation of the posterior palatine arches ; by the three constrictor muscles of the pharynx the bolus is propelled forward into the œsophagus, while the glottis is closed by the constrictors of the larynx, and the drawing upward and forward of the entire larynx under the epiglottis.

(Cleft palate : paralysis of the velum or tongue.)

First stage is voluntary ; the second and third involuntary ; (swallowing while unconscious).

Nervous mechanism :

Nerve centre, in the medulla, for the striped muscles.

Afferent, sensory nerves :

to the soft palate from the 5th ;
to tongue and pharynx, the glosso-pharyngeal ;
to epiglottis and glottis, the superior laryngeal of the vagus.

Efferent, motor nerves :

to the muscles of mastication, branches of 5th ;
to levator palati, the facial ;
to the pharynx, the glosso-pharyngeal ;
to the muscles of the larynx, the inferior laryngeal of vagus ;
to tongue, the hypoglossal ;
to the œsophagus, the vagi, and the ganglia in its walls.

Peristalsis of the œsophagus (Globus hystericus.)

Effect on circulation, etc. Every time the act of swallowing takes place, the heart's action is accelerated; blood pressure falls; necessity for respiration diminishes; while many movements (labor pains, erections) are inhibited.

These effects are brought about reflexly.

CHAPTER V.—GASTRIC DIGESTION.

THE STOMACH.

Comparative anatomy; stomachs of carniverous and herbiverous animals; ruminants.

Historical: Alexis St. Martin.

(Removal of the entire stomach in dogs, and in one or two human beings.)

Function of the stomach.

Structure: peritoneal, muscular (longitudinal, circular, oblique), submucous and mucous coats;

glands: peptic (chief and parietal cells) and pyloric;

lymphatics, and blood-vessels;

nerves: from the pneumogastric and the sympathetic, (splanchnic, from solar plexus.)

Capacity of the adult stomach about one quart; capable of dilatation and contraction.

Secretion of gastric juice.

In the intervals of gastric digestion the mucous membrane of the stomach is pale, and covered with a layer of mucus; either neutral or slightly alkaline in reaction.

The secretion of the gastric juice is in the first place a reflex act, taking place only after an appropriate stimulation, mechanical, thermal, or chemical. But it is also connected with the higher centres by means of branches of the vagus and solar plexus of the sympathetic, and the secretion may be affected by emotions, sight, smell, or thought of food.

Nervous mechanism:

centre in the medulla;

afferent nerve, the vagus;

efferent nerve: fibres of the sympathetic which convey the impulses from above to the blood-vessels and glands concerned in the secretion.

(Action of certain drugs on the secretion. Alcohol in small quantities increases; in large, decreases the secretion. Dilute alkalies, if given before food, increase the secretion.)

GASTRIC JUICE.

A pale, clear, colorless or straw-colored fluid; sp. gr. 1003; acid reaction.

Quantity in 24 hours, about 10 to 20 pints: 8 to 14 lbs., one-tenth of body weight.

Essential Constituents are HCl and two enzymes, pepsin and rennin: (also a proteid, probably a peptone), some mucin, and inorganic salts.

HCl. Maximum amount 0.2 to 0.3 per cent.

(Tests: methyl-violet solution changed to blue; congo-red solutions and test paper, changed from red to blue.)

(The lactic acid which undoubtedly occurs in the stomach during digestion, results from the fermentation of carbo-hydrates.)

The HCl supposed to be formed in the parietal cells of the peptic glands, from the neutral chlorides of the blood.

Pepsin or pepsinogen acts only in an acid medium. Gastric digestion is the result of the combined action of pepsin and HCl.

Pepsin is a proteolytic enzyme; optimum temperature 37° to 40 C. (98°–104°F.); (80°–176°C. destroys moist pepsin).

Artificial gastric juice.

(Chemical alterations in the gastric juice in some acute and chronic maladies.)

Rennin: milk-curdling enzyme.

Cannot act without the presence of lime salts.

Will act in a perfectly neutral medium.

Optimum temperature 104°F. (40°C).

It changes the soluble caseinogen into an insoluble modification, curd, (upon which the pepsin and HCl then act), and the soluble whey-proteid, which latter passes into the whey.

(Rennin disappears into cancer of the stomach and in chronic gastric catarrh.)

DIGESTION IN THE STOMACH.

Gastric and intestinal digestion go hand in hand, and it is not possible in a given case to say with certainty how much of the food will undergo digestion in the stomach and how much in the intestine.

From time to time portions of the semi-liquid contents of the

stomach (chyme) are forced into the duodenum by the peristaltic action of the stomach, and the digestion is completed in the intestines.

The first morsels of food which reach the stomach find it almost free from acidity, and the juice which at once begins to be secreted, is at first neutralized, and the amylolytic digestion is allowed to continue. For about ten minutes after digestion has begun there is no free HCl in the stomach, but long before the end of an ordinary meal peptic digestion is well under way.

Action of Gastric Juice on Proteids:

The final result is the formation of peptones, but the process is complicated.

The proteid, whether soluble or insoluble, is converted into acid-albumin, called syntonin, principally by the HCl.

Syntonin, under the action of the pepsin, takes on water, and undergoes hydrolytic cleavage, with the formation of two soluble proteids, known together as primary albumoses or proteoses, and separately, as proto- and hetero-proteose.

(Proteose used by some as a general term applying to the intermediate product from any proteid, while albumose is given to that proteose from albumin; globulose to that from globulin, etc.)

Each of these proteids again takes up water, and undergoes cleavage, with the formation of a second set of soluble proteids, called secondary, or deutero-proteoses.

These finally undergo further cleavage and become peptones.

The whole process is progressive, although the first and last products may be in the same liquid at the same time.

The object is to get the proteids into a form in which they can be absorbed more easily, the peptones being soluble in water, and easily diffusible through animal membranes.

(Chemically true peptones are not precipitated by saturation of the liquid by Ammonium sulphate(?).)

(There is a progressive decrease in the per cent. of C, and an increase in the per cent. of O.)

Rennin is the enzyme in the gastric secretion possessing the property of coagulating milk.

The digestion of the curd is carried on by the pepsin, and later in the intestines by the trypsin, just as that of the other proteids, with the formation of proteoses and peptones.

Action of Gastric Juice on the Carbohydrates and Fats. It has no direct action, for no amylolytic ferment, but some digestive activity may continue until the growing acidity destroys the activity of the ptyalin of the saliva.

Lusk has shown that cane sugar can be inverted to dextrose and levulose in the stomach. (*Vide* Intestinal Digestion.)

Probably the heat of the stomach is sufficient to liquify most of the fat eaten, and the mechanical movements of the stomach, together with the digestive action of its juice upon the proteids and albuminoids with which fats are commonly mixed, bring about such a mechanical mixture of the fats with the chyme as to facilitate their digestion in the intestines.

Action of Gastric Juice upon the Albuminoids.

Gelatine is, from a nutritive standpoint, the most important. The action of the pepsin upon this is practically identical with that upon the proteids.

Intermediate products are formed similar to the albumoses, named gelatoses or glutoses, and are converted into gelatine-peptones, etc.

The latter conversion is effected much more readily, if not entirely, by the trypsin of the pancreatic juice.

Chyme is the material sent out from the stomach, and is variable in composition, containing beside digested materials, quantities of undigested or partially digested proteids, and other substances not acted upon in the stomach, which have been reduced to a fluid, or semi-fluid consistency, which are ready to be subjected to complete digestion in the intestines.

(Some animals, and one woman, have been able to survive the loss of the stomach, but that does not prove that it is not necessary, or at least not useful, in digestion.)

Duration of Gastric Digestion, from two to five hours.

Vomiting, the act of expelling the contents of the stomach, is generally preceded by a feeling of nausea—secretion of saliva—retching. Begins with an inspiration, glottis closed, abdominal muscles contract.

Antiperistalsis of the œsophagus assists, and the stomach walls also probably contract.

In children it requires but little effort, and is in general produced by the walls of the stomach alone.

Nervous influence.

The *centre* lies in the medulla, and is in relation with the respiratory centre.

The afferent impulses may start from the mucous membrane of the soft palate, pharynx, root of the tongue;

nerves of the stomach (vagus);

uterine nerves;

mesenteric nerves (inflammation of the abdomen, hernia, etc.);

nerves of the urinary apparatus (renal calculi);

nerves of liver and gall duct (vagus), (gall stones);

nerves of the lungs (phthisis);

from the cerebrum, through the special senses, or in consequence of tumors and inflammations.

The efferent impulses are carried by the phrenic nerves to the diaphragm;

by the vagus to the œsophagus and stomach, and by the intercostals to the abdominal muscles.

(Section of the vagi generally, but not always, prevents vomiting.)

During continued violent vomiting, antiperistalsis of the duodenum may occur, forcing bile into the stomach.

Emetics: local, (mechanical, or chemical); general, acting upon centre; or, both *e. g.* tart. em.

General emetics usually produce considerable depression, and the vomiting lasts longer; they also increase the salivary, gastric, and respiratory secretions.

Anti-emetics, also local (ice), or general or both.

Rumination, or Merycism, may be voluntary and acquired.

CHAPTER VI.—INTESTINAL DIGESTION.

After leaving the stomach, the food undergoes most important changes in the small intestines, although the digestion is only completed during its slow progress through the large bowels.

In the small intestines the pancreatic juice, bile and intestinal juice act together, but it will be of advantage to consider them separately.

ANATOMY OF THE INTESTINES. Small intestines; 20 ft. (duodenum, jejunum, ileum); ileo-cocal valve.

Valvulæ conniventes; Villi.

Large intestines: 4 to 6 ft. (cœcum (appendix), colon, rectum).

Glands; Brunner's, Lieberkuhn's, Peyer's (solitary, or "patches").

Nerve plexuses: Auerbach's, between the muscular coats, (peristalsis); Meisner's, in the sub-mucosa, (regulating the calibre of the vessels).

PANCREAS. Anatomy: lobes, lobules, intralobular, and intramediary ducts; alveoli.

Nerves from the hepatic, splenic, and superior mesenteric, with branches from the vagus and sympathetic.

Functions of the Pancreatic Juice. A clear, colorless alkaline fluid.

Contains *trypsin*, a more powerful proteolytic enzyme than pepsin; acts best in an alkaline medium, but also in neutral and even in not too strongly acid media.

Products of tryptic digestion are also proteoses and peptones, but the process is different from that in the stomach.

The preliminary stage of a soluble proteid, as syntonin, is skipped as well as that of the primary proteoses. The proteids fall at once, by hydrolytic cleavage into deutero-proteoses, and these are transformed into peptones, (ampho-peptones).

Under the action of trypsin the proteid does not swell up as with pepsin, but is eroded directly, the indigestible parts preserving the original shape and falling to pieces when shaken.

Pepsin cannot act any further upon the ampho-peptones, but trypsin can, producing a number of other final products, of which leucin and tyrosin (amidoxyphenylpropionic acid), are the longest and best known.

Probably the proteids of the food receive their final preparation for absorption in the small intestines.

Albuminoids are acted upon in the same way, and gelatine-peptones are produced from the stage of gelatose.

Amylopsin acts upon starch and converts it into maltose and dextrine, as does the ptyalin.

The end-products are: a sugar, maltose, and the intermediate achroodextrines, according to the completeness of digestion.

The action of the ptyalin is reinforced by the amylopsin and this

by another enzyme formed in small quantities in the walls of the intestines themselves.

Steapsin, the fat-splitting enzyme has never been isolated, but its action can be demonstrated in the fresh gland.

It splits neutral fats, by hydrolysis, into glycerine and the fatty acid found in the particular fat.

At the temperature of the body the action is very rapid. Rapidity also influenced by the nature of the fat. Fats with a high melting point less easily decomposed than those with a low; (even spermaciti, a body related to fat whose melting point is 125°, is decomposed by steapsin).

A large part, perhaps much the larger part, of the fat remains unaffected and is absorbed into the blood as neutral fat. Probably the small part, split into glycerine and fatty acids, helps to emulsify the balance of the fat, and thereby renders its absorption possible

Emulsification of fats is the breaking up of an oil into minute globules which do not coalesce.

The main cause of this has been shown to be the formation of fatty acids due to steapsin, and to the union of these with the alkaline salts present, to form a soap, which, it has been suggested, forms a thin coating, or membrane, around the small oil-drops, thus preventing them from uniting.

This action of the pancreatic juice is much assisted by the bile, which does not possess any fat-splitting enzyme of its own. Perhaps it furnishes the alkaline salts to make soap.

THE LIVER.

Anatomy ; lobes, lobules ; liver cells.

Capillaries from the portal vein, hepatic artery, hepatic veins, hepatic ducts.

Gall bladder ; cystic duct, hepatic duct ; ductus communis choledicus.

Bile.

2½ lbs. in 24 hours (20 to 40 oz.)

Contains bile salts ;
fatty substances ;
pigments ;
mucus ;
inorganic salts ;
gases.

(Pettinkofer's test for bile-salts; sulphuric acid and cane sugar.)
(Gmelin's test for bile-pigments, nitric acid.)

Functions of the Bile.

I. Excrementitious, to separate excess of C (H) from the blood; remove waste products of metabolism *e. g.* cholesterine, lecithine, bile-pigments; (stercobilin, hydrobilirubin, urobilin).

II. As a digestive fluid:
assists in emulsification and saponification of fats;
assists the absorption of fatty matters;
stimulates peristalsis;
indirectly, prevents putrefaction;
neutralizes peptic digestion.

Glycogenic Function of the Liver.

Glycogen found in the liver by Claude Bernard, 1857.

Has general formula given to vegetable starch $(C_6H_{10}O_5)_n$ and is frequently called "animal starch." Can be discovered microscopically in the liver cells.

It is derived mainly from the carbo-hydrates of the food, which reach the liver as dextrose and levulose, but which are converted into glycogen by the liver cells, by a process of dehydration. Can also be derived from proteid food, showing that the proteid molecule is disassociated into a nitrogenous and a non-nitrogenous part, the latter being converted into glycogen by the liver cells.

Fats take no part in the formation of liver-glycogen.

Function of Glycogen.

It forms a temporary reserve supply of carbo-hydrate material which is laid up in the liver during digestion, and which is gradually made use of in the intervals between meals.

It is probable that the conversion of glycogen back into dextrose depends upon the metabolic activity of the liver cells. The glycogen derived from proteids has the same function to fulfil, it is converted into sugar and eventually oxidized in the tissues. Some of the sugar of the blood formed from the glycogen may, under certain circumstances, be converted into fat in the adipose tissue, instead of being burnt, and thus be retained as a reserve supply of food, more stable than is the glycogen.

By this action of the liver the percentage of sugar in the blood is kept nearly constant (0, 1 to 0, 2 p. c.) within limits best adapted for the use of the tissues.

In our bodies, outside of the liver, the voluntary muscles contain the largest amount of glycogen. In resting muscle from 0,5 to 0,9 p. c., and in the whole body, (the musculature), as much as in the liver.

The muscles have therefore also a glycogenic function, as demonstrated by Kulz (1890). They are also capable of storing up in the form of glycogen any excess of sugar brought to them which may be rapidly reconverted into sugar, and oxidized with the liberation of energy. Muscular exercise will quickly exhaust the supply of muscle- and liver-glycogen, provided it is not renewed by new food.

Urea Formation by the Liver.

The N contained in the proteids of the food is finally eliminated mainly in form of urea. It has been demonstrated that the liver cells are capable of forming this from the carbonate of ammonia. Important function of the liver.

Intestinal juice, succus entericus, derived from Lieberkuhn's crypts, is more abundant in the lower part of the tract.

It is a yellow liquid, with strongly alkaline reaction, due to the presence of sodium carbonate (0,25—0,50 per cent.).

Upon proteids and fats it has no specific effect.

Upon carbo-hydrates an important action :

I. It contains an *amylolytic enzyme*, which assists the pancreatic juice in converting starch into maltose and dextrine.

II. It contains *two inverting enzymes*, by which it converts cane sugar (saccharose) into dextrose and levulose ; and maltose or dextrine into dextrose.

All starch is absorbed into the blood in the form of dextrose.

These inverting enzymes are found more abundantly in the mucous membrane than in the secretion, and it is probable that this last step in the series of digestive changes takes place in the act of absorption by the walls of the intestines.

DIGESTION IN THE LARGE INTESTINES. Observations have been made in cases where, by an artificial anus, the lower part, the rectum, has been practically isolated. From these it has been found that the secretion is mainly mucus, very alkaline, with probably no enzyme of its own.

No doubt some of the digestive processes continue in the mass which passes through the ileo coecal valve, but of more interest are the absorption, and the bacterial decomposition.

Bacterial Decomposition.

Bacteria of various kinds have been found in the alimentary tract, from the mouth to the anus. In the stomach, under normal conditions, the strong acidity prevents the action of those putrefactive bacteria which decompose proteids, and greatly retards the action of those which set up fermentation in the carbo-hydrates. Under certain conditions, (dyspepsia,) bacterial fermentation of carbo-hydrates may be considerable. From two recent cases of fistula of the ileum at its junction with the colon, it was found that the contents of the intestine, at the point where they are about to pass into the large intestine, are acid, provided a mixed diet is used, the acidity being due to organic acid (acetic, 0, 1 p. c.). This must have come from the bacterial fermentation of carbo-hydrates, and a number of bacteria capable of producing this were isolated. The putrefaction of the proteids was prevented by these acids. This protection is however limited, and an excess of proteids in the diet, or a deficient absorption from the smaller intestines was found sufficient to cause putrefaction of the proteids as well as of the carbo-hydrates. In the large intestine the reaction is decidedly alkaline, and whatever of the proteids remain undergo putrefaction. If excessive, it may lead to intestinal troubles.

Among the products thus formed are :

leucin, tyrosin, indol, skatol, phenols, and various members of the fatty acid group, (as lactic acid, butyric, caproic,) N_2S, and H.

Impossible to determine their use.

Some promote the movements of the intestines, some are absorbed into the blood to be eliminated in a different form in the urine.

Movements of the Intestines; most marked in the smaller.

Peristalsis ; aperistalsis ; euperistalsis ; dysperistalsis : anti-peristalsis.

Nervous influence. Reflex through the plexuses of Auerbach, and the vagus. The presence of chyme acts as the normal stimulus ; absent when empty, *e. g.* during sleep.

The splanchnics of the sympathetic are inhibitory.

The lower part of the large intestines is influenced by the sacral nerves (augmentor) and by the lumbar (inhibitory).

Duration of intestinal digestion. Opinions vary, about 12 hours in the small, and 24 to 36 in the large.

The contents of the large intestines, become more solid, acquire the odor (from indol and skatol) and consistence of fæces and are finally passed out by the act of defæcation. Too rapid peristalsis causes liquid fæces.

DEFÆCATION. The undigested and indigestible parts of the food, together with some of the debris and secretions of the alimentary tract, are carried slowly through the large intestine by its peristaltic movements, and eventually reach the sigmoid flexure and rectum. Here the nearly solid mass, by its pressure, produces a distinct sensation on the sensory nerves of the rectum and a desire to defæcate.

The fæces are retained in the rectum by the action of the two sphincter muscles of the anus. One, the internal, is composed of involuntary muscle, and is innervated by fibres arising partly from the sympathetic, and in part from the sacral spinal nerves, through the nervus erigens. This one is in a state of tonic contraction until the act of defæcation begins.

The external sphincter is composed of voluntary muscles and is to a certain extent under the control of the will, but may be overcome if the stimulus to the other becomes too intense.

The reflex stimulation passes through the lumbar spinal cord.

The voluntary factor, originating in the cerebrum, consists in the inhibition of the internal sphincter, deep inspiration, and the contraction of the abdominal muscles. (Action of the levatores ani.)

The connection with centres of the cerebrum is farther shown by the effects of various psychic states upon the act.

In early infancy it is essentially involuntary.

Fæces. The average quantity of solid fæcal matter varies with the quantity and character of food; about 5–7 oz. on a mixed, and on a vegetable diet 12 oz.

Reaction often acid, from lactic acid, derived from the carbohydrates, or from other acids, the result of bacterial putrefaction.

May be neutral or feebly alkaline when much mucus.

Composition; contains (1) indigestible, (2) undigested material, (3) products of bacterial decomposition, (4) cholesterin, probably from the bile, (5) excretin, (6) mucus and epithelial cells, (7) pigment, (8) inorganic salts, (9) micro-organisms.

The odor is stronger after flesh diet, dependent upon indol and

skatol, the results of bacterial decomposition (indol as indican, and skatol as skatoxl-sulphuric acid, in the urine).

Color depends upon the bile pigments, and the degree of change they have undergone, also upon the color of the food taken.

After food with much blood, fæces brownish-black, from hematin;

After food with much vegetables, brownish-green, from chlorophyl.

Preparations of iron taken make the fæces black, from the sulphide of iron formed.

Mucus mixed with the fæces comes from the upper part of the intestines; the less it is mixed with them, the lower the part of the intestine from which it is derived.

SECTION III.

ABSORPTION.

The process of absorption has for its objects, the introduction into the body, through the blood, of fresh materials from the food, *external absorption*, or absorption from without :—and the gradual removal of parts of the body itself, *internal absorption*, or absorption from within.

Both take place through the blood-vessels (veins) and lymphatics, to which latter the term *absorbents* is frequently applied.

CHAPTER I.—ABSORPTION FROM WITHOUT.

Food stuffs, having been converted into absorbable end-products, reach the blood by two routes.

I. They pass directly into the blood, and then through the liver (by the portal vein) and thence into the general circulation ;

II. Or reach the blood more slowly, through the lacteals and lymphatic system.

Absorption takes place by osmosis, less by filtration and imbibition, and through the active part played by a selective power of the epithelial cells.

Osmosis, or dialysis, = diffusion through an animal membrane, and mixture (to a uniform composition) of two liquids capable of mixing—independently of pressure.

(*Imbibition* always preliminary to osmosis).

Filtration is the passage of fluids through a membrane owing to pressure.

(Endosmosis—Exosmosis—Endosmometer—Endosmotic Equivalent.)

We find the conditions in the mucous membrane of the alimentary canal—blood and lymph on the one side and the end-products of digestion on the other—requisite to produce endosmosis.

Absorption in the Stomach.

In surprising contradiction to former ideas, it has been found that

Water is practically not at all absorbed in the stomach. What is drunk is almost immediately squirted out through the pylorus, very little being absorbed.

Alcohol is absorbed readily.

Salts, if in concentrated solution, are readily absorbed, the process being assisted by condiments or alcohol.

Sugars and peptones can be absorbed, but with difficulty, the more concentrated the more easily; assisted again by condiments and alcohol.

Fats are not all absorbed in the stomach.

Absorption in the small intestines.

The soluble products of digestion are mainly absorbed here, as well as the emulsified fats, by the veins and lacteals. Food begins to pass into the large intestines in from 2 to 5¼ hours after it has been eaten, but it is 9 to 23 hours before the last portion reaches the end of the small intestines, including the time spent in the stomach.

Absorption in the large intestines.

The contents pass through very slowly, on an average, in 12 hours. They enter fluid, and leave it as nearly solid fæces.

Sugars and peptones, left over, are absorbed in part, and in part decomposed by the action of the bacteria. Possibility of absorption even when not reduced to proteoses and peptones is shown by the effects of rectal enemata of eggs and milk on nutrition. It has been shown that even fats have been absorbed.

SUMMARY OF ABSORPTION.

Proteids, mainly in the small intestines, and in the form of proteoses and peptones, because these are more diffusible; but it is now generally believed that the initial act is dependent, in some way, upon the properties of the epithelial cells, lining the mucous membrane.

The proteoses and peptones are transmitted directly to the blood capillaries—but they are not found in the blood, and when injected behave like foreign bodies, even as toxines. Hence probably changed, in the act of being absorbed, into a serum-albumin, by a process of de-hydration.

Sugars. Starches are converted in the intestines into maltose,—or maltose and dextrine,—and these, by the inverting enzyme of the mucous membrane, into dextrose.

Cane sugar into dextrose and levulose before absorption, and milk sugar into dextrose and galactose.

In general, therefore, the carbo-hydrates are eventually absorbed in form of dextrose (and levulose,) leaving out the small amount which, normally undergoes fermentation by bacteria.

The sugar of the blood exists in the form of dextrose, a form readily oxidizable by the tissues.

(Cane sugar injected into the blood is eliminated in the urine—dextrose, if slowly injected is all consumed.)

Absorption here too does not take place according to the known laws of osmosis, hence it also is a special act dependent upon the living epithelial cells.

Like the proteids they pass directly into the blood and not into lymph vessels.

Fats, are absorbed chiefly in a solid form, as an emulsion, into the villi of the intestines, (lacteals).

The fat globules pass from the epithelium to the central lymphatic, through the interstices in the adenoid tissue, with the stream of lymph constantly circulating from the blood through the stroma to the lacteals.

They therefore reach the blood through the lymphatic system, (thoracic duct).

Water and salts, are absorbed especially in the intestines, both small and large. In the small, in ordinary amounts entirely through the blood-vessels of the villi, not the lacteals; —in the large, by the activity of the epithelial cells.

CHAPTER II.—ABSORPTION FROM WITHIN.

LYMPHATIC SYSTEM.

Lymphatic vessels. The larger ones resemble, with their three coats, small veins; the smaller ones have only a connective tissue coat lined with endothelium. Provided with valves, opening towards the heart.

The lymph capillaries take their origin, in the tissues;
- in so-called lymph spaces;
- in the stomata, or mouths, between the endothelial cells on the surface of serous membranes;
- in perivascular lymph spaces;
- in the villi of the intestines, as the lacteals.

They ultimately discharge into the venous system, at the junction of the internal jugular, and subclavian veins, at the base of the neck, on the left side through the *thoracic duct*, and on the right through the *right lymphatic duct*.

(Difference in contents of the two ducts.)

In some part of their course all lymphatic vessels pass through **lymphatic glands,** 2 to 20 mm. in diameter, made up of lymph follicles, and consisting of capsule, trabeculæ, and alveoli. In the alveoli is the lymphoid tissue containing the lymph-corpuscles or leucocytes, resembling white blood corpuscles. The glands occur in groups in the flexures of the limbs, the recesses of the neck, and the thoracic and abdominal cavities, (cervical, axillary, inguinal, mesenteric).

In passing through the glands poisonous matter which has been absorbed by the lymph may be deposited, and thus its entrance into the blood prevented;

the lymph becomes coagulable, and the number of leucocytes is largely increased.

Lymph, is under ordinary circumstances, a clear transparent, yellowish, slightly alkaline fluid, with saline taste, bathing all the tissue elements. It contains many waste products of tissue changes (urea, cholesterine, etc.), also that which remains after the tissues have taken from the blood the materials needed for their nutrition, and which has still nutritive properties too valuable to be lost, and which is therefore to be returned to the circulation, through the veins.

Origin of the lymph is by filtration, or by secretion from the plasma of the blood, through the walls of the capillaries.

Chyle, which is the lymph as found in the lacteals, is an opaque, milky, neutral or slightly alkaline, albuminous fluid, containing the emulsified fat of the food, ("molecular basis").

Quantity of Lymph secreted in 24 hours is very great, according to Dalton, 3½ to 4 pounds.

Movements of the Lymph and Chyle depend upon:

1. Vis a tergo, (new absorption);
2. General muscular contraction, and other intermittent external pressure;
3. Contraction of the walls of the intestines and lymph vessels;
4. Inspiratory movements of the chest, dilating the ducts;
5. The suction force of the passing blood in the subclavian veins, (Dalton).

[A substance in solution injected into the blood can be identified in the lymph of the thoracic duct at the neck in from 4–7 minutes after injection. Accumulation of lymph constitutes dropsy; anasarca; œdema.]

SECTION IV.

CIRCULATION.

CHAPTER I.—THE BLOOD.

FUNCTIONS OF THE BLOOD.

1. It carries to the tissues *food-stuffs* after they have been properly prepared by the digestive organs.
2. It carries to the tissues *O* absorbed from the air in the lungs.
3. It carries off from the tissues various *waste-products* of dis-assimilation, (urea, uric acid, H_2O, CO_2, etc.).
4. In warm-blooded animals it aids in equalizing the *temperature*.

It is contained in a set of closed tubes, within which it is kept in circulation by the force of the heart-beat.

PHYSICAL PROPERTIES.

Color, varies from a bright scarlet to a deep dark bluish-red, depending upon the Hb in different degrees of oxidation.

It is opaque on account of the different refractive power of the plasma and corpuscles. ("Laky" blood, in which by chloroform, *e. g.*, the coloring matter has been discharged into the plasma, is transparent.)

Odor, depends upon the presence of volatile fatty acids, and differs in different animals and in man.

Taste, saltish, due to the salts dissolved, principally NaCl.

Sp. gr. varies from 1055 to 1063.

Quantity, about $\frac{1}{12}$ to $\frac{1}{14}$ of the body weight.

Temperature, varying in different parts and conditions of the body, is on an average 100°F.; (in hepatic veins 107°F.).

CHEMICAL PROPERTIES.

Reaction, alkaline, due to sodium carbonate and di-phosphate.

Alkalinity, diminished by muscular exercise, during coagulation, in old blood, after use of acids, in anæmia, uræmia, rheumatism, high fever, diabetes, and in earlier stages of cholera.

Contains: **Water,** holding inorganic matter in solution, and the corpuscles in suspension.

Proteids, including albumin, the nutritive principle, which is carried to the tissues for their nourishment and repair; para-globulin, and fibrinogen which with a specific ferment produce the fibrin of the clot.

Fatty matters, temporarily increased by oleaginous food; generate heat and force by their oxidation, or are deposited as adipose tissue.

Inorganic salts, the chlorides, carbonates and phosphates of Na and K and Mg.; give alkalinity to the blood; aid in osmosis; promote the absorption of CO_2 from the tissues; and assist in holding the other substances in solution (Na salts in the plasma, K salts in corpuscles.)

Excrementitious matters, kreatin, urea, etc., which are taken from the tissues to the excretory organs.

Gases in solution or loose chemical union, in varying proportions.

Variations in composition of healthy blood.

In men, higher sp. gr. and more red corpuscles.

During pregnancy, lower sp. gr.

In fœtus, more solid matters and colored corpuscles. This condition continues sometime after birth; during childhood amount of solid matter diminishes until adult life, when it rises, again to diminish in old age.

More solid matter and red corpuscles in plethora and sanguineous temperaments.

Diet usually produces a temporary effect, but it may be more lasting.

Bleeding reduces the sp. gr. very rapidly, owing to absorption of fluid from the tissues of the body.

In different parts of the body: arteries and veins; in the portal, hepatic and splenic veins; in the veins from an active gland.

Abnormal variations: Polyæmia, plethora, mellitæmia, uræmia, lipæmia, uricacidæmia, lithæmia.

Oligæmia vera, anæmia, chlorosis, etc.

HISTOLOGICAL STRUCTURE.

Blood consists of a liquid part, *the plasma*, in which are suspended the corpuscular elements, *red and white corpuscles* and the *blood-plates*.

Red corpuscles, in mammals, are biconcave, non-nucleated discs, consisting of a highly elastic stroma, within which is a solution of hæmoglobin. When shed, these tend to run together into rouleaux, like piles of coin.

Size, from $\frac{1}{3500}$ to $\frac{1}{3200}$ inch in diameter, in man.

Number about 5,000,000 per cubic mm. (Hæmocytometer).

The number is less (4,500,000) in females; varies, with age; greatest in fetus and new-born child; with constitution, nutrition and manner of life; with time of day; a distinct diminution after meals; in females, increased by menstruation, decreased by pregnancy; residence in high altitudes is followed by a marked increase in their number.

Color singly under the microscope, yellowish-red, in mass blood-red, varying according to amount of hemoglobin, Hb.) (Hæmoglobinometer.)

Hb when decomposed breaks up into a proteid—(globulin, 96 per cent,) and a simpler pigment, (hematin, 4 per cent.) *Hematin* seems to be oxidized hæmochromogen, the O being in a feeble combination which may readily be broken up, with liberation of the O.

Hb has the property of uniting loosely with O in certain definite proportions, forming a true chemical compound, called *oxyhæmoglobin*, formed whenever blood or Hb solutions are brought in contact with O. If placed in an atmosphere containing no O, the oxy-Hb will be disassociated, giving off O and leaving behind Hb, or as it is frequently called "*reduced Hb.*" (Respiration).

Hb forms with CO (carbon-monoxide) a compound similar to oxy-Hb., known as *carbon monoxide-Hb.*, but much more stable, hence breathing CO, one of the constituents of coal gas, is liable to prove fatal. Even a more stable and fatal combination is formed by the union with NO (nitric oxide).

With CO_2 (carbon dioxide) the combination is less stable.

(Bohr suggests that the O unites with the hæmochromogen and the CO_2 with the proteid. It, as well as the blood-plasma, may therefore act also as carrier of the CO_2.)

The property of combining with O seems to be dependent upon the presence of iron, which is in connection with the hæmatin, in the proportion of from 0,335 to 0.47 p. c. Hb and its compounds crystallize with varying degrees of rapidity in blood made "laky" by the addition of ether; and in various shapes, according to the animal from which taken. Solutions of Hb and its compounds give distinctive absorption bands when examined with the spectroscope.

Derivatives of Hb:

Methb. = oxy-Hb.

Hæmochromogen, hæmatin (*vide supra*).

Hæmin, a compound of hæmatin with HCl; much used in medico-legal cases for the detection of blood, since the crystals are very characteristic, and are readily obtained from bloodstains or clots, no matter how old these may be.

Hæmatoporphyrin, is "iron-free hæmatin", obtained by the action of strong sulphuric acid on hæmatin.

Hæmatoidin, a crystalline substance found in old blood clots, identical with bilirubin.

(*Histohæmatins* are a group of pigments said to be present in many of the tissues, *e. g.*, the muscles, supposed to be respiratory in function, related, physiologically, if not chemically, to Hb.)

Hb is regarded as the parent substance of the bile and urinary pigments.

Origin and fate of the red blood corpuscles.

In the adult the organ for the reproduction of the red corpuscles is the red marrow of the bones, principally the ribs; in the embryo, also the liver and spleen.

Hæmatopoiesis goes on continually. A group of nucleated, colorless cells, erythroblasts, in the red marrow, multiply by karyokinesis, and the daughter-cells eventually produce Hb in their cytoplasm, thus forming nucleated red corpuscles. The nuclei are subsequently lost and the non-nucleated red corpuscles are poured into the blood stream.

They probably undergo disintegration and dissolution while in the blood stream, in any part of the circulation, the liberated Hb being carried to the liver, and excreted in part as bile pigments. (The suggestion that they are destroyed in the spleen is not substantiated by conclusive observations.)

White, or colorless corpuscles, or leucocytes, are not peculiar to the blood; found in milk, lymph, chyle, adenoid tissue, marrow of bones, etc.

They are more or less spherical masses of protoplasm, more or less granular, without cell wall, of varying size, (average $\frac{1}{2500}$ inch), containing one or more nuclei. Found in blood in proportion of 1 to 350–500 of the red; but this proportion is subject to numerous variations.

Varieties: according to Ehrlich, oxyphiles, or eosinophiles, whose granules stain only with acid analine dyes; basophiles, which stain only with basic dyes; and neutrophiles, which stain only with neutral dyes.

A better classification is into *lymphocytes*, small corpuscles with round vesicular nucleus, resembling the leucocytes found in the lymph glands, and probably brought to the blood through the lymph; not capable of amœboid movement.

Mononuclear leucocytes; large corpuscles, with vesicular nucleus, with power of amœboid movement.

Polymorphous, or polynucleated leucocytes, large corpuscles, with the nucleus divided into lobes that are either entirely separate or connected by fine protoplasmic threads, with active amœboid movement.

Probably these are three stages in development, the last being the latest.

Their amœboid movement has given them the name of "*wandering cells*;" some are able to migrate through the walls of the capillaries into the surrounding tissues, normally, but more rapidly under pathological conditions, (diapedesis).

Origin. They multiply in the circulation, by karyokenesis, but the greater number are probably produced in the lymph glands and lymphoid tissues of the body.

Function is unknown. Metschnikoff's theory of phagocytosis is that they protect the body from pathogenic bacteria by ingesting these. They are known to ingest foreign bodies with which they come into contact.

Chemical composition. They contain fibrinogen, and paraglobulin and a diastatic ferment (?), and the nucleus, a nitrogenous phosphate-containing body, and salts principally of K.

Blood-plates, small circular or elliptical bodies of variable size, but always smaller than the red corpuscles.

The latest theory of their origin is that they are fragments of the nuclei of the multinuclear cells which have gone to pieces in the blood.

Besides aiding in coagulation their function is not known.

Chemical composition of the Plasma.

Plasma is the unaltered fluid in which the corpuscles float, a clear, yellow, alkaline fluid.

It contains *Water*, and *Solids* :

proteids ;
fat and extractives ;
inorganic salts ;
grape sugar in small amounts ;
yellow pigment, independent of Hb.;
and gases.

Proteids, are serum-albumin,
paraglobulin,
fibrinogen.

Fats, are tri-olein, tri-stearin, and tri-palmitin.

Extractives, urea, creatin, creatinin, sometimes uric and hippuric acids.

Inorganic salts : The plasma contains an excess of sodium salts, and the corpuscles, an excess of potassium salts.

Chemical composition of the serum.

Serum is the liquid part of the blood after separation of the clot, which cousists of fibrin and the corpuscles.

It is the same as plasma, except as far as the proteids are concerned ; they differ somewhat in nature and amount.

COAGULATION.

No universally accepted theory.

Pekelharing's : fibrin ferment not present in blood-plasma, but formed after blood has been shed. A nucleo-albumin is formed from the broken-down leucocytes, and blood-plates.—The nucleo-albumin, then combines with the calcium salts present in the blood, to form the fibrin ferment, which is an organic compound of calcium. When this comes in contact with fibrinogen a reaction occurs, the calcium passing over to the fibrinogen and forming an insoluble calcium compound, fibrin.

Lilienfeld's : after blood is shed a disintegration of leucocytes and blood-plates occurs, resulting in a giving off of nuclein compounds to the plasma.

These nuclein substances, being dissolved in the alkaline plasma, come in contact with the fibrinogen and decompose it, with the formation of thrombosin. This latter then unites with the calcium salts to form fibrin, which is according to this theory, a calcium compound of thrombosin.

We may say, there are these **three fibrin factors** :

fibrinogen ; nucleo-proteid ; and *calcium salts.*

The first and last exist in the circulating blood, but the nucleo-proteid is formed usually only after the blood is shed, and is derived from the disintegration of the leucocytes and blood-plates.

Fibrin when fresh has a pale yellow or whitish color, filamentous structure, and is singularly elastic.

Insoluble, in water, dilute saline solutions and in ether.

In 1 p. c. of HCl it is converted into acid-albumin and dissolved.

If blood be drawn into an open vessel, in about eight or nine minutes the whole mass will have become solid or jelly-like, forming the *crassamentum or clot*.

In a few minutes, a straw-colored fluid (serum,) will be seen to transude, at first from the top, then from the sides, until the clot, in the course of an hour or two floats in the liquid. The first drop of serum appears on the surface of the clot 11 or 12 minutes after the blood has been drawn, and the fluid continues to exude for 36 to 48 hours.

The clot consists of the corpuscles entangled in the fibrin.

When the clotting is delayed, so as to allow the corpuscles to sink before the fibrin has formed, the upper stratum differs from the lower in being of a greyish-yellow color (*buffy coat, or crusta phlogistica*).

This contracts also more than the rest of the clot, and causes a "*cupping*" of the surface.

This takes place in inflammatory conditions, and was formerly considered of great importance.

Intravascular clotting—may be induced by the introduction of foreign particles, solid or gaseous (air), or by injuring the inner coat of the blood-vessels, (*e. g.* by ligature).

Blood does not clot within the blood-vessels, because nucleo-proteids are not present in sufficient quantity at any one time. When blood is shed the leucocytes and blood-plates break down in mass, and the restraining action of the endothelial cells of the vessels is eliminated.

Coagulation may be hastened, by: (a) Increasing the extent of surface with which the blood comes in contact; thus by motion or application of sponge or handkerchief to a wound. (b) Moderate heat. Hot sponges or cloths will hasten the process. (c) Watery condition of the blood (clot soft). (d) Addition of small quantity of water. (e) A supply of O. (*Cf.* a.)

Coagulation may be retarded, by: cooling, checked at freezing point; by the action of neutral salts ($MgSO_4$ in 27 per cent. solution, 1 part to 4 of blood), (the addition of water in sufficient quantity to salted blood allows it again to clot), by peptones and albuminoses injected into the circulation; by extracts of leech heads; by oxalates of Na and K, (1 per cent.), (the addition of water will not allow clotting), by imperfect aeration, as in asphyxia; in inflammatory states; by exclusion from the air, by oil, etc.; by addition of large quantity of water.

Where there is in the blood a want of those substances which produce coagulation, it does not take place if a vessel is wounded; (hæmophilia; hæmorrhagic diathesis; "bleeders").

Tendency to this condition is met with in scurvy, typhus, plague, yellow fever, and poisoning by phosphorus.

Coagulation takes place in the body from ten to twenty-four hours after death.

Gases in the blood. O, CO_2, and N. Arterial blood contains relatively more O and less CO_2 than venous, but the absolute quantity of CO_2 is in both kinds greater than that of O.

The chief part of the O is found in the corpuscles, loosely combined with Hb, as oxy-Hb.

Besides a small quantity of CO_2, contained in loose chemical combination in the corpuscles, the greater part exists, either in a state of simple solution in the plasma, or in a state of weak chemical combination, probably with bi-carbonate of soda.

The whole of the small quantity of N is simply dissolved in the plasma and does not vary much.

The venous blood coming from an active secreting gland differs very little in its composition, gaseous and otherwise from typical arterial blood.

CHAPTER II.—CIRCULATORY APPARATUS.

In order to fulfil its function the blood must circulate. It passes from the left ventricle, as a starting point, back to it again, through two circles, called the systemic, and the pulmonary circulations:—both carried on by means of the contraction of the heart.

THE HEART.

A hollow pear-shaped organ, (weight in male 10–12 oz., in female 8–10 oz.), loosely enclosed in a sac, the *pericardium*, and consisting of four cavities, (*two auricles* and *two ventricles*).

Both ventricles are more capacious than the auricles, and the right auricle more capacious than the left.

The muscular wall of the left ventricle 3-4 times as thick as that of the right.

The *heart muscle* stands between the striated skeletal and the smooth muscle. The fibres are made up of short oblong cells, without sarcolemma, often branched and anastomosing. Each cell has a nucleus. The striæ are not as distinct as in skeletal muscles. Many fibres pass from one auricle to the other, and from one ventricle to the other.

The heart, hangs as it were, suspended by the large vessels which proceed from its base, obliquely from right to left, $\frac{2}{3}$ of it being to the left of the mid-sternal line.

Its apex, formed by the left ventricle, is in contact with the chest wall and beats against it at a point where the so-called *apex beat*, (in the fifth left intercostal space, and about three inches from the mid-sternal line,) is most distinctly seen or felt.

The interior of the heart is divided into two chief chambers by a longitudinal partition, and each of these two again into two others by horizontal partitions. We thus have a right and a left heart, each divided into an auricle and a ventricle.

The aperture of communication between the auricle and ventricle of each is guarded by valves so arranged as to prevent a reflux of the blood into the cavity from which it has been forced. On the right side this valve is called the *tri-cuspid*, and on the left, the *mitral* or *bi-cuspid*.

The bases of the cusps of the valves are attached to the tendonous rings which encircle the orifices of the auricula-ventricular openings, their ventricular surface and borders are fastened by slender tendinous fibres, the *chordea tendinea*, to the *columnæ carneæ*, or *musculi papiliares*, which are bundles of muscular fibres projecting from the internal surface of the ventricles.

The bicuspid valve is considerably stronger and thicker than the tricuspid.

The *semilunar valves* guard the orifices of the pulmonary artery, passing out of the right ventricle, and of the aorta passing out of the left ventricle. Each valve consists of three parts, of semilunar shape, their convex margins being attached to a fibrous ring at the junction of the artery to the ventricle, the concave or nearly straight border being free, so as to form a little pouch. In the centre of the

free edge of each pouch, which contains a fine cord of fibrous tissue, is a small fibrous nodule, the *corpus Arantii*, from which, and from the attached border fine fibres extend into every part of the middle substance of the valve, except a small space just within the free edge, on each side of the corpus Arantii.

Opposite each of the cusps is a bulging of the wall of the vessel; these are the *sinuses of Valsalva*.

The whole interior of the heart is lined with endothelium.

The heart is *nourished by the coronary arteries*, which arise from the aorta near the sinus of Valsalva, and are closed during systole by the aortic valves.

They have no collateral circulation. Sudden closure of their blood supply causes stoppage of the ventricular contraction. (Angina pectoris.)

ARTERIES. These begin in a single trunk, the aorta from the left ventricle, and running usually in situations protected from pressure and other dangers, divide into smaller and smaller branches, usually at an acute angle to supply the head, trunk, and extremities. The area of the branches generally exceeds the area of the parent trunk. Anastomoses and communications are frequent.

The *walls* of the arteries consist of three principal coats, external or tunica adventitia, the middle or tunica media, and an internal or tunica intima.

The walls of the arteries are provided with nutrient vessels, the vasa vasorum.

Most are surrounded by a plexus of sympathetic nerves, with frequent ganglia.

The arteries gradually grow smaller, (*arterioles*,) until before uniting with the minute veins, they are reduced to

CAPILLARIES. The minute vessels which compose the capillary net-work maintain the same diameter throughout, and the meshes of the net-work are more uniform in shape and size than those formed by the anastomoses of the minute arteries and veins.

Their walls are composed of a single layer of flattened elongated nucleated cells, between which, here and there, may be seen pseudostomata. In the larger capillaries the cells rest on a finely fibrillated membrane.

Their *diameter* varies; common size is about $\frac{1}{3000}$ in.

The *number* of capillaries, and the size of the meshes determine

the vascularity of a part, and the more active the functions of an organ, the more vascular.

The sectional area of the capillaries is about 800 times that of the arterial system, and about 300 times that of the greater veins.

VEINS. The venous system begins in small veins (*venules*), which are slightly larger than the capillaries from which they spring.

They unite to form larger and larger trunks, until they end (in the systemic circulation) in two veins, the *venæ cavæ, ascendens* and *descendens*, and the *coronary veins*, which enter the right auricle; and (in the pulmonic circulation) in four pulmonary veins, which enter the left auricle.

The total *capacity* diminishes as they approach the heart; but as a rule their capacity is two or three times that of the corresponding arteries.

Their *structure* resembles that of the arteries, but in the large veins near the heart (venæ cavæ, and pulmonary) the middle coat is replaced for some distance from the heart by circular unstriped muscular fibres, continuous with those of the auricles.

They have *valves*, similar to those described, but with their free margins turned towards the heart; semi-lunar; single, or, in large veins, three or four together. In some, altogether absent as in bones, internal organs and central nervous system. Lymph spaces are present in the walls of both arteries and veins.

CHAPTER III.—ACTION OF THE HEART.

At the same time that the right auricle is distended by the blood from the venæ cavæ, the left auricle is distended by the blood from the pulmonary veins, (*auricular diastole*).

Suddenly both auricles contract, (*auricular systole*).

The blood is forced into the ventricles; valves close; ventricles become distended, (*ventricular diastole*).

They then simultaneously contract, (*ventricular systole*).

During the ventricular systole the auricles are receiving a new supply of blood.

Immediately after the systole there is a period of "*repose*," the auricular-ventricular orifices are open, and the blood which has accumulated in the auricles during the ventricular contraction and while the auriculo-ventricular orifices were closed, now flows into the vent-

ricles, and its place is taken by fresh blood from the venæ cavæ and pulmonary veins.

The valves on the right side of the heart do not close as perfectly as those on the left side, in order to prevent rupture of the delicate structure of the lungs in case of an excess of blood, or increased pressure in the pulmonary capillaries.

The auricular systole, the ventricular systole, and the "repose" constitute a "*cardiac revolution*" or "*cardiac cycle*," and together last in man a little less than a second, (usually taken as a second). Auricular systole $= \frac{2}{10}$; ventricular systole $= \frac{4}{10}$; "repose" $= \frac{4}{10}$,

[or more exactly (.8 second) as follows:

auricular systole = .1; ventricular systole = .3;

auricular and ventricular diastole = .4;

auricular diastole = .7; ventricular diastole = .5;

auricular or ventricular systole = .4].

These vary with the pulse rate.

The ventricular systole, however, remains nearly uniform.

(.4 second) whatever the pulse rate.

Movements of the Heart.

At each ventricular systole the heart muscle contracts, causing it to harden, shorten, twist from left to right, and to move forward against the chest wall producing the apex beat.

This is felt most distinctly in the 5th left intercostal space, 2 in. below the nipple, and 1½ in. to its sternal side (or 2 in. to the left of the sternum, or 3 inches from the mid-sternal line).

It varies in position, force, and extent.

(Cardiograph, Marey's.—The tracing or cardiogram shows a small elevation corresponding to the auricular systole, succeeded by a large abrupt rise, corresponding to the beginning of the first sound, and caused by the ventricular systole. The rise is maintained, with small secondary oscillations, for about .3 of a second, then gives way to a sudden descent that marks the relaxation of the ventricles, the beginning of the second sound and the closure of the semilunar valves. An interval of about .5 second elapses before the curve begins again to rise at the next auricular contraction. *Vide infra*. Pulse.)

Sounds of the Heart. (Physical diagnosis.)

Two sounds are normally heard at every beat of the heart, in quick succession, followed by a pause, or period of silence: "lūb-dŭp").

The "*first sound*," dull and prolonged, is heard best in the region of the cardiac impulse, or "apex beat;" its commencement coincides with the impulse of the heart against the chest wall, and just precedes the radial pulse.

Causes not precisely known, but probably the sound of the contraction of the muscle, and the vibration of the auriculo-ventricular valves, and of the chordæ tendineæ, (and flow of blood?).

(When the mitral valves are prevented from closing (experimentally) the first sound is replaced by a "murmur.")

The first sound may be imitated by the syllable "lub."

The "*second sound*" is shorter and sharper, and follows closely after the radial pulse (dŭp).

Caused by the closing of the semilunar valves, and is altered or replaced by a "murmur" when these are diseased.

Heard best over the junction of second right costal cartilage and sternum, where the aorta comes nearest to the surface.

The *1st is systolic, i.e.*, occurring during the ventricular systole, *the 2nd, diastolic*, beginning at the commencement of the diastole.

If cardiac cycle be divided into tenths, 1st = 4, 2d = 2, and the pause = 4.

Variations of the Heart Sounds.

They may be weakened or inaudible,
or increased or reduplicated.

Murmurs may take the place of the sounds.

Friction sounds may be heard, due to pericarditis.

Changes connected with disease of the tricuspid valve are heard best in the third to the fifth intercostal space, just to the right of the sternum, and over the right border of that bone.

Changes in connection with diseases of the pulmonary valve are heard best over the second left intercostal space, near the edge of the sternum.

(Systolic murmurs often heard without valvular lesions.)

Frequency and Force of the Heart's Action.

The heart of a healthy adult male contracts 72 times in a minute, but this number, corresponding with the radial pulse, varies according to many circumstances:

Age:—frequency diminishes from the commencement to near the end of life, and rises in extreme old age:

just after birth, 140–130;
during 1st year, 130–115;
about 7th year, 90;
about 14th year, 85;
adult male, 72; female, 80;
old age, 70–60;
in decrepitude, 75.

Sex:—at all ages somewhat quicker in the female.

Size:—in persons of same sex and age the shorter one has the more rapid rate.

Position of the body:—the rate greater when standing than when sitting, and than when recumbent.

Muscular activity increases rate.

Taking food increases rate.

Influenced by psychic events.

Time of day, independent of food and exercise. The rate sinks from morning to mid-day, then rises, and sinks again towards evening.

Rate is affected by respiration, (*q. v.*).

Increase of temperature raises the rate.

Atmospheric pressure:—the rate increases with elevation.

Idiosyncrasies.

Local peculiarities:

in the brain; arrangements for regulating the supply, (cerebro-spinal fluid);

in erectile tissues; corpora cavernosa, corpus spongiosum, clitoris, nipple;

in lungs, liver, and kidneys, *q. v.*

Velocity of the pulse wave about 8.5 metres per second in the upper extremities in a man, and 9.5 metres in the lower limbs, or not much less than 500 miles in 24 hours.

The velocity of the blood stream about $\frac{1}{30}$ as great. (Stromuhr.)

A portion of the blood can traverse the entire circulation in about 20 seconds: all the blood may pass through the heart in from 25 to 50 seconds.

The normal relation between frequency of pulse and respiration 3 or 4 to 1, is not always kept up in disease.

Palpitation ; due to

organic conditions ; conditions of blood pressure ;

irritability of cardiac muscle, or of nerves ;

(reflex ; emotional, gastric or intestinal, results of excesses.) (Tachycardia, *vs.* Brachycardia.)

Syncope, or fainting. (*Cf.* cardio-inhibitory centre.)

Blood pressure is due to the following facts :

each contraction of the heart sends from 4 to 6 oz. of blood into the already full arteries ;

the arteries are distensible, and stretch to accommodate this extra amount of blood, (kinetic energy stored as potential) ;

there is a distinct "*peripheral resistance*" to the passage of the blood from the arteries into the veins, due to the friction in the enormous number of capillaries into which the main artery is broken up ; (*vide* Capillaries). (Influence of *vaso-motor centre.*)

The blood-pressure is greatest in the left ventricle, and at the beginning of the aorta (4 pounds, 4 ounces avoirdupois); gradually lessening as we go from the arteries near the heart to those more remote, and again from these to the capillaries along the veins to the right auricle. (Mercurial manometer.) (Kymograph.)

The blood-pressure is nowhere very great in the veins, but is greatest in the small veins : in the large veins towards the heart there is a "negative pressure" ; the action being that of suction rather than pressure forward.

In the arterial blood-pressure the chief factors are, the cardiac contractions, and the peripheral resistance. (Variations.)

The Pulse is an expansion of the artery produced by the wave of blood set in motion by the injection of blood, at each ventricular contraction, into the already full aorta. The wave passes on the surface of the more slowly travelling blood-current already contained in the vessel, producing the pulse as it proceeds.

The pulse is not, therefore, perceptible at the same moment in all arteries of the body ; the delay in the beat is in proportion to the distance from the heart.

A pulse tracing (*sphygmogram*), no matter upon which artery the sphygmograph be applied has the same general characteristics, viz. :

a sudden rise, due to the sudden injection of blood into the full arteries ;

a gradual descent, due to the recovery of the arteries by their recoil;

the decline is usually marked by a distinct notch—the dicrotic notch, caused by a more or less marked ascent of the lever at that point by a second "dicrotic" wave.

In addition we may have a pre- and a post-dicrotic wave.

The *dicrotic wave* is generally believed to be present, to a greater or less degree, even in arteries which are perfectly healthy, and is probably due to the rebound from the aortic valves, which causes a second wave. It indicates therefore the closure of the aortic valves.

(An interruption in the upstroke, called the *anacrotic wave*, is usually associated with disease of the arteries, atheroma or aneurism.)

When the resistance in the periphery is greatly diminished by the dilatation of the small arteries and capillaries, so much blood passes on from the arteries into the capillaries, at each stroke of the heart, that there is not sufficient remaining in the arteries to dilate them. Thus the intermittent current of the ventricular systole is not converted into a continuous stream by the elasticity of the arteries before the capillaries are reached. Thus intermittency of the flow occurs in capillaries and veins, and a pulse is produced, (*venous pulse*).

The same may occur when the arteries become rigid from disease, and when the beat of the heart is so slow or feeble that the blood has time to pass on to the capillaries at each cardiac systole before the next stroke occurs, the amount sent at each stroke being insufficient properly to distend the arteries.

The pulse may be hard or soft, quick or slow, strong or weak, large, small or thready.

The intermittent flow of the blood from the heart is converted into a continuous flow in the capillaries by the elasticity of the blood-vessels.

The Flow in the Capillaries is seen to be uniform, the red corpuscles moving almost in single file and bending in various ways to accommodate themselves to the tortuous course of the vessels, but instantly recovering their normal shape on reaching a larger vessel. Along the walls of the vessels is seen the so-called "*still layer*" of liquor sanguinis, which appears to be motionless. The colorless corpuscles move slowly on the outer edge of the stream, more slowly if they get into the still-layer, and sometimes, collecting in a capillary, prevent for a time the passage of the red corpuscles, (*Stasis*).

The white corpuscles may be seen at times working their way through the walls of a vessel by amœboid movements, and by the same process of diapedesis the red corpuscles may be squeezed through the wall in the case of impeded venous circulation causing increased blood pressure.

The flow in the capillaries is maintained,

by the ventricular systole ;

by the elasticity of the arteries ;

by their own vital contractility.

The flow in the veins is maintained,

by the vis a tergo of the ventricular contraction ;

by the compressing action of the muscles ;

by the suction action of the heart.

(The valves prevent regurgitation, and the anastomoses prevent serious obstruction.)

CHAPTER IV.—INFLUENCE OF THE NERVOUS SYSTEM ON THE HEART.

The action of the heart depends in part upon the property of rhythmical contractility, residing in the muscular walls, therefore automatic, and as was formerly almost universally supposed, upon the presence of the **intrinsic ganglia,** of Remak, (motor), of Ludwig, (inhibitory), and of Bidder, (accelerator), as in the frog.

(Stannius' experiment of ligating between the sinus and the auricles, and then between the auricles and ventricle, whereby the muscle stimulus is completely blocked.)

The influence of the central nervous system is exerted in two directions : *slowing* or *inhibiting* the beats, through the fibres of the *vagi* nerves, and

accelerating or *augmenting* them through *sympathetic* fibres.

The fibres of the vagi constantly bear inhibitory impulses to the intrinsic nerves of the heart, therefore exert a tonic inhibitory influence on the rapidity of the heart beat.

The action of one vagus is sufficient to regulate the heart's rhythm.

Stimulation of the vagus slows the pulse, and produces large and full diastole.

Section of the vagus causes an exceedingly rapid pulse.

The *cardio-inhibitory centre is in the medulla*; is always in operation, but its action may be reflexly increased by stimulation of almost any afferent nerve, particularly by the abdominal sympathetic, (*e. g.* by a blow on the epigastrium).

Accelerating or augmenting fibres pass from the cervical portion of the spinal cord through the communicating branches to the upper dorsal sympathetic ganglia and thence to the heart.

Stimulation of these ganglia or of the branches to the heart quickens its beat, but only after a comparatively long time (ten seconds), and the effect continues for a considerable time after the stimulus has been removed. They are less powerful than the inhibitory fibres of the vagi.

[*Other centrifugal heart-nerves* have been supposed to exist. Pawlow divides the inhibitory and augmentor nerves into four classes:—(1) nerves inhibiting the frequency of the beat; (2) nerves inhibiting the force of the contraction; (3) nerves augmenting frequency; (4) nerves augmenting force.]

Centripetal or afferent nerves of the Heart.

Nerve impulses pass from the heart, probably having their origin in its inner lining, to the medulla. These appear to be of two kinds. One, going by way of the vagi, affects the cardio-inhibitory centres, and diminishes the heart's rate; the other, the depressor, in the nervus laryngeus, affects the vaso-inhibitory centre and lowers the blood pressure, by lessening the tone of the splanchnic area.

Increase of the intraventricular pressure stimulates both sets of fibres. Over-filling of the heart retards its beat, and causes a fall of arterial pressure. Thus an equilibrium is maintained between the general blood-pressure and the force of the heart-beat.

The circulation of venous blood appears to stimulate the inhibitory centre, and, of highly oxygenated blood, the augmentor fibres.

Effects of poisons on the cardiac contractions.

Atropine augments the heart-beats, and when acting upon the heart prevents the effects of vagus stimulation.

Muscarine markedly slows the heart, and in larger dose stops it; similar to vagus stimulation; can be prevented by atropine.

Digitaline slows the heart and seems to stimulate the vagus. Later on the muscle becomes more irritable.

Veratrine and *aconitine* produce same effect.

Nicotine at first slows the heart by stimulating the inhibitory endings of the vagus; followed by exhaustion of the terminals and consequent quickening of the heart-beat.

Curare in large doses paralyzes the inhibitory fibres.

Vaso-motor Centres.

Vaso-motor fibres come *primarily* from a *nucleus of grey matter in the medulla*, in the floor of the 4th ventricle, between the calamus scriptorius and the corpora quadrigemina. Thence they pass down in the spinal cord, and, issuing with the anterior roots of the spinal nerves, traverse the various ganglia of the prævertebral cord of the sympathetic, and, accompanied by fibres from these ganglia, pass to their destination, the muscles in the walls of the vessels. This centre in the medulla is always active.

Secondary vaso-motor centres exist *in the spinal cord*.

The influence of both may be altered in various ways, mainly by afferent impulses. These may either increase or diminish the usual action of the centres, which maintains a medium "tone" of the arteries.

The lesser centres, usually under the control of the main centre in the medulla, are capable of originating impulses themselves.

The vaso-motor centre may not only be reflexly affected by afferent impulse from the vessels themselves, and by stimulation of any large sensory nerve, but may also be affected by impulses proceeding from the cerebrum, as in blushing, or pallor from mental emotions.

Among the so-called vaso-motor nerves there are some which on stimulation cause a dilatation of the vessels, these are the *vaso-dilators*, while others cause contraction, these are the *vaso-constrictors*. Both kinds are often found in one and the same anatomical nerve, *e.g.* the sciatic.

(The tone of the arteries may be diminished by inhibiting the activity of the vaso-motor centres by stimulation of a certain *afferent* nerve, passing from the inner surface of the heart to the centre in the medulla, (the depressor nerve). Seems to act by lessening the tone of the vessels governed by the splanchnic nerve. *Vide infra*.)

Stimulation of the vaso-motor system increases blood pressure.

Depression of the vaso-motor system lowers it by dilating the vessels.

Asphyxia raises it by stimulating the centre by the increased amount of CO_2.

Section of the spinal cord lowers it.

Paralysis of the vaso-motor nerves supplying the abdominal vessels lowers it all over the body, because these vessels are capable of containing all the blood in the body, and so take it from the rest of the vascular system.

The reflex vaso-motor activity, constriction or dilatation, appears usually in the vascular area from which the afferent impulses arise (stimulation of nervi erigentes causes dilatation of the vessel of the penis);

it may appear in a part associated in function with the sensory surface stimulated (stimulation of the tongue causes dilatation of the blood-vessels in the submaxillary gland);

may also be bi-lateral, (stimulation of the mucous membrane of the nose may cause vascular dilatation in the whole head. The vessels of one hand may contract when the other is put into cold water).

Work done by the Heart at each contraction can be found by multiplying the weight of the blood expelled by the ventricles by the height to which the blood rises in a tube tied into an artery. This height is about 9 feet. (3.21 m). Taking the weight of blood in the left ventricle, as 6 oz. *i. e.* $\frac{3}{8}$ lb. we have $9 \times \frac{3}{8} = 3.375$ foot-pounds, or (3.21×180 gms. $= 578$ gram-metres), as the work done by the left ventricle at each ventricular systole. Adding to this the work done by the right (about $\frac{1}{4}$ that of the left), we have $3.375 \times .822 = 4.19$ foot-pounds, or 722 gram-metres as the work done by the heart at each contraction, or about *180 foot tons in the 24 hours*, with a pulse rate of 72.

[**Pathological Cardiac Conditions.**

Cardiac Hypertrophy. Any resistance to the onward flow of the blood through the chambers of the heart, or through the vessels, increases the work and therefore the thickness of the muscular walls, with or without dilatation of the cavities.

Obstacles in the vessels; obstacles in the heart.

Hypertrophy of any of the chambers of the heart.

Valvular anomalies.]

CHAPTER—V. VASCULAR OR DUCTLESS GLANDS.

A certain set of organs which resemble each other only in that they are larger in the embryo than after birth, and that although they have a glandular structure, they do not empty their products

through ducts, (hence "ductless")—but directly into the blood current, (hence "blood" or "vascular").

Of their functions but very little is positively known.

In this class are usually grouped,

the adrenal capsules,
the thyroid,
the thymus,
the spleen.

Others include also the tonsils, the *solitary glands* and *agminated glands of Peyer*, (*Peyer's Patches*), the *pineal* and the *pituitary* glands, the *carotid* and *coccygeal* glands.

THE ADRENALS, OR SUPRARENAL BODIES.

Late observations seem to show that their function through life is to remove a toxic body, produced elsewhere in the body, possibly in the muscular system.

Others suppose that they produce a peculiar substance which has a very definite physiological effect, especially upon the muscular system.

Removal causes death.

Intravascular injection of aqueous extract causes prolonged muscular contraction and increase of blood-pressure.

In Addison's disease they have frequently, but not invariably, been found diseased.

Brown-Sequard thought they might be concerned in preventing the over-production of pigment.

Nerve supply rich, from the solar plexus, vagi and phrenics.

THE THYROID GLAND.

Anatomical structure.

Two glandular structures on either side of the trachea, united by an isthmus, made up of groups of minute closed sacs embedded in a stroma of connective tissue, lined with a single row of epithelial cells, and filled with a clear, peculiar albuminoid or mucin-like substance, which lies also in the lymph-spaces between the vesicles.

(Comparative anatomy,)

Para thyroids.
Accessory thyroids.

Function. Two theories:

I. That they remove a toxic substance, formed elsewhere.
II. That they secrete a special colloid material with definite physiological action.

Myxœdema—Cretinism.

Thyroid extract. Thyro-iodine (Bauman), 9.3 p. c. of dry weight of iodine.

THE THYMUS GLAND.

Largely developed in fœtal life; it attains its greatest size early after birth, remains stationary until the 10th to 14th year, and then gradually diminishes until in adult life scarcely a trace of it remains.

Location.—Structure. Composed of numerous little follicles of lymphoid tissue, collected into lobules connected with central stalk.

Function. Seems to take part in producing colored corpuscles, or in the elaboration of the blood during earlier stages of animal life.

[In hibernating animals it persists throughout life, and appears to serve for the storing up of material (*e. g.* fat), by which the respiration and temperature may be maintained during hibernation. Before the hibernating season it becomes enlarged and ladened with fat.]

THE SPLEEN.

The largest of the vascular glands, situated to the left of the stomach, between it and the diaphragm.

About 5 inches in length; weighing about 6 oz.

Structure.

From the tough elastic fibrous capsule trabeculæ pass inward, forming a supporting stroma, in the interstices of which are contained, rounded masses of lymphoid tissue (Malpighian corpuscles), on the course of the fine arterial twigs, and the true spleen pulp.

Spleen pulp consists of cells,
- red corpuscles,
- white corpuscles, granular, resembling lymph corpuscles,
- large cells containing either roundish corpuscles, like red corpuscles, or pigment granules, allied to the coloring matter of the blood.

The splenic artery ultimately terminates in a group of arterioles which do not anastomose with each other, but end either (as elsewhere) in the radicles of veins, or in lacunæ in the splenic pulp from which the veins arise.

Veins large and very distensible, hence whole tissue highly vascular and readily engorged with blood.

Nerve fibres abundant from the splanchnic nerves, (Schæfer).

Chemically the spleen pulp is acid, although the blood is alkaline:
contains a large percentage of iron in an organic compound,
fatty acids, and fats,
cholesterine,
and a number of nitrogenous extractives (uric acid, xanthin, hypoxanthin, leucin, lecethin, etc.), the results of active metabolic changes occurring in the spleen.

Blood of the splenic vein contains an enormously increased number of white corpuscles; the red are smaller, brighter, less flattened, and do not form rouleaux;—contains more water and an unusual quantity of uric acid, and other products of tissue waste.

Functions. (The Oncometer of Roy shows that the spleen undergoes rhythmical contractions and dilatations, at intervals of about one minute, independent of the general circulation, and that it is largest about 5 hours after digestion has begun, (*i. e.* when the digestive organs have almost finished their work, and have again become less vascular.)

Theories (none demonstrated,) of the functions of the spleen are as follows:

i. elaborating the albuminous materials of the food, and for a time storing them up to be gradually introduced into the system as required,
ii. formation of red blood corpuscles,
iii. destruction of red corpuscles,
iv. formation of uric acid,
v. the formation of the enzyme, which, when carried to the pancreas in the blood, acts upon the trypsinogen contained in the gland, converting it into trypsin,
vi. to act as a vascular reservoir, or diverticulum to the portal system.

Changes in the size of the spleen in disease, "ague cake."

Extirpation of the spleen without any marked changes resulting. (Lymphatic glands increased in size—? blood-forming activity of the bone-marrow increased?—diminution of the bactericidal power of the blood?)

THE PITUITARY GLAND.

A reddish grey mass on the sella turcica of the sphenoid bone.

In about 50 p. c. of cases of acromegaly its glandular portion has been found *post mortem* to be greatly enlarged.

Its destruction produces death after muscular weakness, convulsions, dyspnœa, lowered temperature, rapid emaciation, out of proportion to the anorexia.

Function. Administration of the extract causes rise of blood-pressure, partly due to increased force of heart and partly to constriction of the arterioles.

Hence inferred that its function is to prevent accumulation of some special toxic substance.

Some, that it is related to the thyroid and is able vicariously to assume its functions.

(Of the function of the other ductless glands nothing is definitely known.)

SECTION V.

RESPIRATION.

The continuous absorption of O and the excretion of CO_2 is necessary to the maintenance of animal life.

The function by which this interchange takes place is called **respiration.**

Internal or tissue respiration, and External respiration or Breathing.

EXTERNAL RESPIRATION OR BREATHING.

The essential part of an organ of respiration consists of a membrane, separating tissue or blood containing CO_2 from air or some medium containing O; the membrane allowing of osmosis.

(Comparative anatomy. Cutaneous respiration in man very slight, compared with pulmonary exchange, O $\frac{1}{150}$ – $\frac{1}{200}$ absorbed, CO_2 exhaled $\frac{1}{200}$ – $\frac{1}{250}$.)

CHAPTER I.—RESPIRATORY ORGANS IN MAN.

Nares, (pars olfactoria, and pars respirativa). (Effects of mouth-breathing).

Larynx, (structure; cartilages, vocal cords, glottis, ciliated epithelium). (Position of glottis in respiration). (*Vide Voice*).

Trachea, (from the 5th cervical to the 3d dorsal vertebra). (Structure; cartilaginous rings; ciliated epithelium.)

Bronchi, (right shorter, broader, (ciliated epithelium), more horizontal than the left,) divide and subdivide, gradually losing the cartilaginous rings, until with a diameter of $\frac{1}{50}$ inch, they terminate in the primary lobules, (formed only of a thin membrane of areolar and elastic tissue, lined by a layer of squamous epithelium, not provided with cilia).

Lungs, (two, right and left, each enclosed in a serous membrane, the pleura, with its visceral and parietal layers).

Right lung divided into 3, left into 2 lobes. Each lobe divided into lobules, which consist of a branch of the bronchial tube, with its final terminals altered in shape and widened into the air-cells and

constituting the *infundibula* ; a slight amount of areolar tissue, blood-vessels, nerves and lymphatics.

Air cells or vesicles vary in form, and size ; from $\frac{1}{50}$ to $\frac{1}{70}$ inch in diameter ; smaller near the centre of the lung ; network of capillaries denser.

Vesicles of adjacent lobules do not communicate.

Blood-supply, from the bronchial arteries for nutrition ; from pulmonary artery for arterialization.

The pulmonary artery conveys venous blood to the lungs from the right heart, and this blood takes no part in the nourishment of the respiratory tissues.

Outside the cells its capillaries are spread out so densely that the interspaces or meshes are narrower than the vessels themselves, which are on an average $\frac{1}{3000}$ inch in diameter.

Between the atmospheric air in the cells and the blood in these vessels nothing intervenes but the thin walls of the cells and of the capillaries.

Lymphatics : irregular lacunæ in the walls of the air-cells ; irregular anastomosing spaces in the walls of the bronchi, and in the pulmonary pleura. From these spaces they pass in towards the root of the lungs to reach the bronchial glands.

Nerves from the vagi and sympathetic, through branches forming the anterior and posterior pulmonary plexuses.

Thorax ; ribs ; diaphragm.

(Negative pressure ; elastic tension ; effect of puncture of the pleura. Fœtal lungs ; atelectasia ; hydrostatic test.)

CHAPTER II.—MECHANISM OF RESPIRATION.

Respiration consists of the alternate drawing in of air (Inspiration), and expelling it (Expiration), by the alternate expansion and contraction of the thorax.

The cavity of the thorax is enlarged in all diameters by the descent of the diaphragm and the ascent of the ribs.

Inspiration. The inspiratory muscles are, therefore, the diaphragm and those which directly or indirectly elevate the ribs.

(Scaleni, serrati postici superiores, levatores costarum, and the external intercostal. (?))

In forced or labored inspiration the larynx descends, the glottis opens, the palate is raised ; the facial muscles are also involved, there is dilatation of the nostrils, and the patient gasps for breath.

(Muscles called into play: besides the above, serrati postici inferiores, quadrati lumbarum, sterno-cleido mastoid, trapesei, pectorales minores and majores, etc.)

Expiration is essentially a passive process, depending upon the elasticity of the parts, the lungs and the thoracic walls.

During forced expiration the abdominal muscles are always active in further reducing the capacity of the thorax.

Types of Respiration.

The young, without distinction of sex, up to the age of puberty, breathe almost entirely with the diaphragm. This, descending, presses on the abdominal viscera and pushes forward the abdominal walls, giving rise to the *abdominal* (*diaphragmatic*) type of respiration.

In the adult male the chest wall below the 6th rib takes active part in respiration, giving the *inferior costal type*; in the adult female it is principally the upper part, above the 7th rib which is active, irrespective of habits of dress, giving the *superior costal type.*

(Advantages).

Respiratory Rhythm.

The act of inspiring, especially in women and children is a little shorter than expiration, (6:7 in male, 6:8 or 9 in women and children;) and there is a slight pause between the end of expiration and the beginning of the next inspiration.

(Pneumograph.)

Change in this rhythm indicates abnormal conditions.

(Inspiration or expiration relatively lengthened. Inspiratory and expiratory dyspnœa. Cheyne-Stokes respiration.)

The number of respirations per minute in a healthy adult ranges from 14 to 24, averaging 18, so that there are about four heart beats to one act of respiration.

(This relation disturbed in some diseases.)

Circumstances affecting the number of respirations:

- size,
- age,
- position of the body, and state of activity,
- temperature,
- digestion,
- emotions,
- disease, and to a certain extent, the will,

Modified respiratory movements:

coughing, (voluntary or reflex),
hawking,
sneezing, (sternutatories),
sniffling,
gargling,
sighing,
crying,
laughing,
yawning,
hiccough,
sucking,
speaking and singing, (expiratory).

Mechanical Work performed during Respiration.

The force of the respiratory muscles is greatest in individuals of 5 ft., 7-8 in. in height, and can elevate a column of mercury 3 in. Above this height the force diminishes as the stature increases.

Amount of work done = weight multiplied by the height.

Inspiratory muscles do work equal to raising 1.4 lbs. one foot; diaphragm does work equal to 3 lbs.—therefore whole act equivalent to raising 4.4 lbs. 1 foot.

Elasticity of chest walls to be overcome = ¼ more, therefore, 5.5 foot pounds.

Supposing 18 inspirations per minute — 99 lbs. per minute, 5940 per hour, 142,560, or 63 tons per day.

Allowing for less expansion and taking only ⅓, we still have 21 ft. tons as the amount of work performed during inspiration per day.

Expiration being passive is not counted, but under the circumstances of forced expiration, may amount to as much.

[**Relative dimensions of the Chest.**

The diameters measured by callipers; the circumference by cyrtometer.

If arms extended horizontally during moderate expiration the circumference immediately below the nipples, and the angles of the scapulæ = ½ the length of the body.

Circumference immediately under the arms:

in a strong man = 34.3 in.;
in female 34 in.

Circumference at level of the ensiform process:

in man 32 in.;

in female 30.4 in.

Right half usually larger than left; in old persons the upper part is diminished and the lower part becomes larger.

The long *diameter*, from the clavicle to the lowest rib varies very much.

The transverse diameter above and below is,

in man 9.7–10. 1 in.;

in female 8.9–9.2 in.

The antero-posterior (from chest wall to one of the spinous processes,) is

in upper part 6.6 in.;

in lower part 7.4.

The chest of the infant and child differs from that of the adult in the relation between these several dimensions.

Limits of the Lungs.

Limits defined by percussion, mediate or immediate: (pleximeter). The apices reach anteriorly 1.1–2.7 in. above the clavicles.

The lower margin of the lungs is found anteriorly at the 6th and 7th ribs; posteriorly at the 10th, and on deep inspiration as low as the 11th rib.

(Physical Diagnosis.)]

CHAPTER III.—BREATHING- OR VITAL-CAPACITY.

By means of a spirometer it is found that in tranquil breathing about 20 cu. in. are taken into the lungs at each inspiration, and very nearly the same amount given out at each expiration.

This is the "*tidal air*" = 20 cu. in. (only enough to fill the trachea and bronchial tubes).

By forcible inspiration 110 cu. in. can be taken in addition.

This is the "*complemental air*," = 110 cu. in.

By forcible expiration 100 cu. in. can be forced out in addition to the tidal air.

This is the "*reserve*" or "*supplemental air*," = 100 cu. in.

The sum of these, (therefore, 230 cu. in.) is called the "*vital capacity*," which can be defined as the largest amount of air which can be forcibly expelled after a forcible inspiration.

A certain amount of air can never be expelled from the lungs, this is called the "*residual air*," and is approximately estimated at 100 cu. in.

The vital capacity is influenced by height, weight, age, sex, and diseased conditions affecting the mobility of the thorax or expansibility of the lungs.

For every inch of height above 5 ft. 1 in. the capacity should increase 8 cubic inches.

Females have less capacity than males even with same circumference of chest.

VENTILATION.

Atmospheric air is a mixture of O, N, CO_2 and watery vapor, with traces of other gases.

Of 100 vols. of pure air, 79.19 vols. are N,
20.81 " " O; the CO_2 0.03—0.04.

By weight N is 75, O is 25.

The quantity of watery vapor varies greatly.

Air that has been breathed has 79.30 vol. N—16.03 O—4.38 CO_2.

It shows:

i. increased temperature,
ii. increase of CO_2, the amount varying according to
   a. age and sex,
   b. respiratory movements,
   c. external temperature,
   d. season of the year,
   e. time of day,
   f. purity of the respired air.
   g. hygrometric and barometric state of atmosphere,
   h. food and drink,
   i. bodily exercise.
iii. *the O is diminished.*
iv. *its volume is diminished.*
v. *the watery vapor is increased.*
vi. *a small quantity of ammonia* (?) and of *organic matter* is added (to which odor is due).

Although the organism can adapt itself to a vitiated atmosphere without sensible inconvenience, breathing such often, or for a long time, becomes injurious, hence ventilation necessary.

Every healthy person should have at least 700 cu. ft. of *air space*, and every sick person at least 1000 cu. ft., and this should be renewed 2 to 3 times an hour.

Floor space also of importance. In hospitals each individual should have 100 to 120 sq. ft. The minimum of floor space should not be less than $\frac{1}{12}$ to $\frac{1}{10}$ of the cubic air space.

(Hygiene. Various methods of artificial ventilation, in hospitals, barracks, prisons, churches, schools, etc. In well ventilated rooms CO_2 not more than 0.05 to 0.07 vol. p. c.; in badly ventilated rooms as much as 0.25 to 0.30 vol. p. c.; in lecture rooms, etc., may reach 0.70 to 0.80 vol. p. c.—a large gas burner consumes in 1 hour as much O as is required by the average individual in 8 hours. Effects of breathing vitiated air, accidental impurities: dust, germs, etc.)

The **Interchange** between the O in the upper part of the lungs and the vitiated air in the lower part is brought about by diffusion.

In the alveoli the passage of the O from the air into the blood of the pulmonary capillaries, and of the CO_2 in the reverse direction from the blood into the air, is due to the fact that the tension of the O of the air is higher than that of the venous blood, and the tension of the CO_2 of the blood is higher than that of the air.

In addition to this the tissue of the lungs takes an active part in the regulation of this interchange, subject to nervous influence as other glandular epithelium.

The O passing through the intervening membranes enters into chemical union with the Hb of the red corpuscles.

The blood after having passed through the lungs changes,

i. in color,
ii. in amount of O,
iii. in amount of CO_2,
iv. in temperature,
v. in coagulability.

This renovated blood is carried to the various tissues, and the O which has been taken up by the Hb of the red corpuscles (oxyhæmaglobin) is there set free, while the CO_2 enters into loose chemical combination with certain constituents of the blood, or into simple solution, and is carried to the lungs, there to be disassociated and passed out into the air cells.

The interchange of O and CO_2 between the blood and the tissues takes place in the tissues as part of the general nutritive process.

CHAPTER IV.—RESPIRATORY SOUNDS.

Auscultation. Immediate; mediate. Stethescope.

I. **THE NORMAL VESICULAR SOUND** is a full, sighing sound, gradually increasing in intensity to a maximum and then falling away before expiration.

Variously ascribed to sudden dilatation of the air vesicles; to friction of the current of air against the walls of the alveoli; to the air passing through the glottis, modified by its passage to the alveoli.

In children, up to the age of 12, generally sharper on account of smaller size of the vesicles.

The expiratory sound is usually heard in children but may be absent in adults during quiet breathing. It is feeble, sighing, loudest at first, soon disappearing; 3 to 4 times shorter than the inspiratory sound.

When prolonged or loud it becomes a suspicious symptom.

II. **THE BRONCHIAL, LARYNGEAL OR TUBULAR SOUND** is loud, rough, harsh; heard both during in- and expiration, of equal intensity and duration throughout. Best heard between the scapulæ, on a level with the 4th dorsal vertebra (bifurcation of the trachea); under normal circumstances it is usually obscured by the vesicular sound in other parts of the chest.

(Physical diagnosis).

Pathological sounds are either modifications of the normal sounds, or new ones.

(Puerile breathing. Extended tubular sounds. Cavernous, amphoric sounds.

Râles.—Fremitus, etc.)

CHAPTER V.—THE NERVOUS MECHANISM OF THE RESPIRATORY MOVEMENTS.

Partly under the control of the will, the movements of respiration are carried on involuntarily and automatically, co-ordinated by the respiratory centre located in the lower part of the medulla oblongata.

THE CENTRE is bilateral, the two parts being connected into a single centre by commissural fibres.

Each half acts more or less independently of the other, although

synchronously with it, and each is connected with the lungs and muscles of respiration of the corresponding side.

Each half is composed of an inspiratory and an expiratory part or centre: the former being also in a sense an accelerator, and the latter an inhibitory centre. The accelerator is the more excitable and the more potent, and always acting.

Supposed (?) subsidiary centres in brain and cord exert their influence only through the medullary centre.

The rhythmic sequence of the respiratory movements is due to the rhythmic activity of the centre dependent upon the stimulation of the blood.

The rhythm as well as the rate, force and other characters of the discharges from the centre may be materially affected by the will, emotions, by the composition, supply, and temperature of the blood, and by various afferent impulses. The ordinary factors are the quantity of O and CO_2 in the blood, and the impulses conveyed from the lungs by the fibres of the pneumogastric nerves.

THE AFFERENT RESPIRATORY NERVES are the pneumogastric, glosso-pharyngeal, trigeminal, and cutaneous nerves.

The pneumogastric are the most important. They contain fibres which affect the expiratory centre, and fibres which affect the inspiratory centre. Excitation of the superior laryngeal nerve causes expiratory stimulation: (cough for expulsion of foreign bodies).

The glosso-pharyngeal also connected with the expiratory centre, hence, during swallowing, the breathing is arrested, to prevent the aspiration of food or drink into the larynx.

Irritating gases may cause respiratory arrest by exciting either the sensory fibres of the trigeminal nerves in the nose, or the pneumogastric (vagi) in the larynx or lungs.

Odorous gases may affect respiration through the olfactory nerves. Excitation of the splanchnic, the sciatic, and sensory nerves in general, influences the number of respirations.

Stimulation of the cutaneous nerves, cold douche, slapping, etc., has a tendency to increase the number and depth of respirations, but finally causes cessation in expiration.

Afferent (intercentral) fibres connect the brain cortex and probably the ganglia at the base of the brain, with the respiratory centres.

THE EFFERENT RESPIRATORY NERVES are the phrenics, certain spinal nerves, and the pneumogastrics.

During respiration the glottis is opened by impulses to the larynx through the recurrent or inferior laryngeal branches of the vagi.

During forced breathing other nerves involved, spinal, facial, hypoglossal, and spinal accessory.

(In utero the fœtus contains relatively a large amount of O, hence in an apnœic condition. Any attempt to breathe draws in amniotic fluid which strongly irritates the sensory fibres of the mucous membrane, and causes inhibitory impulses. After birth cleanse mouth and nose: artificial respiration: atalectasis.)

Apnœa, due to gaseous or mechanical factors; *i. e.* too much O in the alveoli, or depression of the irritability of the respiratory centre.

Polypnœa, thermopolypnœa, or **heat-dyspnœa,** the result of increased temperature of blood or cutaneous surface.

Dyspnœa; O-dyspnœa, cardiac and hæmorrhagic; CO_2-dyspnœa, due to products of muscular activity in the blood.

Hyperpnœa, (*Cf.* polypnœa) exaggerated breathing, usually due to excess of CO_2.

Asphyxia, ("pulselessness"); three stages, *hyperpnœa*; developing *dyspnœa*, (expiratory efforts increased) and convulsions; and finally *collapse.* Heart continues feebly beating for several minutes after cessation of respiration. After death the blood almost black; arteries empty; veins and lungs engorged.

Artificial respiration.

Marshall Hall's method, patient on face, etc.

Sylvester's method, patient on the back, etc.

Periodical *traction of the tongue* facilitates both methods, and is sometimes of itself sufficient.

Effects of respiration on the blood-pressure, and pulse.

Inspiration increases, and expiration decreases the blood-pressure in the arteries.

During inspiration, the pulse rate is more rapid than during expiration, and the pulse wave is affected, the dicrotic notch being more pronounced.

Effect of chloroform on the respiratory centre.

According to the Edinburgh School the respiratory centre is always first paralyzed. Confirmed by the Hyderabad Commission. But other observations show that chloroform may paralyze the heart without affecting the respiration, and that the paralysis of the vasomotor centre, and the consequent withdrawal of blood from the heart and brain to the dilated splanchnic area, may be an important factor in bringing about a fatal result. (Advantages of inverting the patient and compressing the abdomen, in threatening symptoms during chloroform anæsthesia.)

SECTION VI.

VOICE AND SPEECH.

CHAPTER I.—VOICE.

Nearly all air-breathing vertebrates have arrangements for the production of sound or voice. (Examples.)

In man the sound-producing mechanism consists of :

I. **THE TRACHEA,** through which the blast of air is blown ;

II. **THE LARYNX,** with the vocal cords, by the vibrations of which sound waves are set up ;

III. **THE UPPER RESONANCE CHAMBERS,** the pharynx, mouth, and nasal cavities, in which the sounds are modified and intensified and in which independent notes and noises arise.

(**TRACHEA,** *vide* **RESPIRATION.**)

THE LARYNX is a cartilaginous box (*thyroid*, *cricoid* and *two arytenoid*) across which are stretched from front to back, two thin sharp-edged membranes, the *true vocal cords.*

The thyroid covers only the front of the larynx, the cricoid is a complete ring, the back portion being much broader than the front.

On the top of this broad part are the arytenoids, connected by a joint, with synovial membranes and ligaments, and therefore capable of movements on the cricoid.

The cords are attached in front to the inner angle of the thyroid, and behind to the vocal or anterior processes of the arytenoids.

The thyroid can rotate on a horizontal axis on the cricoid, and can therefore be depressed by the contraction of the *crico-thyroid muscle*, and the cords thus be stretched.

The cords are separated from each other (abducted) by the contraction of the *posterior crico-arytenoid muscles*, which are attached to the external or muscular processes of the arytenoids. The rima glottidis is thereby widened.

The cords are adducted and the rima narrowed by the contraction of the *lateral crico-arytenoid muscles*, which approximates the anterior processes of the arytenoids.

The arytenoids themselves are shifted on their articular surfaces somewhat nearer the middle line by the contraction of the *transverse* or *posterior arytenoid muscle*, which helps also to narrow the glottis.

The *thyro-arytenoid muscles* are incorporated in the cords, and their main function is to alter the tension of the cords.

Nerve Supply.

The crico-thyroid muscle is supplied by the *superior laryngeal branch of the vagus*, which also contains the sensory fibres for the mucous membrane of the larynx above the vocal cords.

It conveys to the mind the sensation of the state of the muscles, necessary for their intelligent guidance.

All the other intrinsic muscles are supplied by the *recurrent* or *inferior laryngeal of the vagus*, which receives these motor fibres from the spinal accessory. It supplies sensory fibres to the mucous membrane of the larynx, (below the cords,) and of the trachea.

Movements of the cords during respiration.

During inspiration the rima glottidis opens widely, by the action of the posterior crico-arytenoid muscles.

During expiration these muscles relax, and the larynx resumes its original position, half open.

Before a cough or sneeze the rima is entirely closed.

Voice.

At the emission of sound the edges of the cords are approximated, and their tension is increased.

The shorter the cords the higher the note.

The tenser the cords the higher the note.

The lower limit of the voice is fixed by the maximum length of the cords.

In the child the cords are short; in woman, longer; in the adult man, longest.

Length and tension normally correspond.

The range of an ordinary voice is 2 octaves; by training 2½; in exceptional cases 3, and even 3½ has been known.

Essentials to production of pure sounds.

elasticity of cords and smoothness of edges ;

accurate *adjustment* and close approximation, through whole extent :

a certain continued state of *tension :*

air must be propelled through glottis by forced *expiration.*

Pitch depends upon length and tension of the cords and the strength of the expiratory blast.

Quality depends upon the partial tones produced in the upper resonance chambers, therefore upon the nature and form of the resounding walls, of the larynx and upper air chambers.

Quality with pitch, gives rise to the varieties of singing voices : bass and tenor ; contralto and soprano. Between the former the barytone ; between the latter the mezzo soprano.

(Children's voices ; boys', puberty ; old age.)

Falsetto.

The anterior part of rima is wider, the posterior part closed.

The resonance is chiefly in the upper cavities, pharynx, mouth, and nose.

Only the free edge of the cords vibrates, one or more nodes or motionless lines, parallel to the edge, being formed by the contraction of the interior part of the thyro-arytenoid muscle, which thus acts like a "stop" upon the cord. (Oertel).

CHAPTER II.—SPEECH.

Combinations of sounds form *language.*

Articulate sounds are divided into *vowels* and *consonants.*

Vowels are musical sounds ; consonants are noises, due to irregular vibrations, not to regularly recurring waves.

Vowels are produced by the vibrations of the cords ; the consonants are due to the rushing of the expiratory blasts through certain constricted portions of the resonant cavity above the larynx : *e. g.* lips, (labials) ; teeth, (dentals) ; nose, (nasals).

When vowels are uttered, the soft palate closes the entrance to the nasal cavity entirely, if not, a nasal character to the voice. (Post-diphtheritic paralysis.)

Nervous mechanism of Speech.

The *abductor muscles* are not employed in the production of voice ; they are associated only with the function of *respiration.*

The *adductor muscles* are not brought into requisition in respiration, but are associated with the function of *speech*.

Corresponding to this we find the adductors alone are represented in the cortex of the brain, the abductors in the medulla.

The adductor movements are more likely to be affected by functional changes, the abductor by organic disease.

Speech Centre is found

In the third frontal convolution in the left hemisphere. (Broca's convolution), in right-handed persons.

(Aphasia — Aphonia.— Ataxic aphasia or aphæmia.— Amnesic aphasia.—Paraphasia.—Agrammatism.—Bradyphasia.)

Stammering is due to spasmodic contraction of the diaphragm.

Stuttering, to inability to control the lips and tongue.

Whispering is speech not accompanied by action of the vocal cords, or speech without voice.

(Laryngoscope.)

SECTION VII.

ANIMAL HEAT.

CHAPTER I.—TEMPERATURE.

Homoiothermal (warm-blooded) animals, (mammals and birds) preserve a comparatively constant temperature independent of the changes taking place in the temperature of the surrounding medium.

Poikilothermal (cold-blooded) animals (fish, reptiles, amphibia, and invertebrates) have a temperature varying with that of the surrounding medium.

The difference between the temperature of the two classes is a relative, not an absolute one.

The temperature of the various species of animals varies, and is different in different parts of the organism.

Rectal temperatures generally taken.

Mammals have nearly the same temperature as man but a little higher, birds considerably higher.

(Measurement of temperature. Thermometers; clinical thermometers; surface; for use in mouth, axilla, rectum or vagina; metastatic thermometer; thermo-electric needles.)

Average temperature of man.

The mean axillary temperature 98°.8F. (37°.1C.); in mouth about 0.3–0.5C. higher; in rectum from 0°.3 to 1°.5C. higher; and in the vagina from 0°.5 to 1°.8C. higher.

(Temperature of the different regions of the body).

Conditions and circumstances affecting the bodily temperature.

Age. Before birth and immediately after, the temperature is higher than that of the mother. It soon falls about 1°C. and then rises in the next 24 hours to about 99°.0 or 99°.5F. (37°.4 or 37°.5C.).

It very slowly sinks until full growth is attained, when the normal mean temperature of adult life is reached.

After the age of 45 or 50 it declines until about the age of 70, when it begins slowly to rise until in very old persons it approaches that of very young infants.

In the old the increase is due not to increased heat production, but lessened dissipation.

(Variable in children ; easily disturbed.)

Sex makes no appreciable difference, although according to some the mean temperature of the female is said to be higher, while according to others, lower than that of the male.

Constitution. Individuals with vigorous constitutions have a slightly higher temperature than the weak.

Diurnal variations are noted. The maximum from 5 to 8 P. M. (mean 7 P. M.) ; minimum from 2 to 6 A. M. (mean 4 A. M.)

Diet influences the temperature : insufficient lowers, and full tends to cause a rise.

Slight rise during *digestion*, but quickly dissipated.

Hot drinks and solids tend to augment, and cold to lower bodily temperature.

Activity of mind and body. All conditions which tend to increase metabolic activity tend to raise the temperature. The heat thus produced is quickly diffused and rapidly radiated.

(Muscular, mental, glandular activity ; shivering.)

Surrounding temperature does to a slight degree influence the bodily temperature. The mean in warm climates is 0.5C. higher than in cold ones, irrespective of race. Hot dry air better endured than hot moist air. Baths exercise a decided influence. Hot baths increase, cold lower. Local application of heat causes the bodily temperature to sink, but the cutaneous temperature of the part to rise.

Drugs, organic substances and *micro-organisms* variously affect bodily temperature.

Vascularity of a part affects the temperature.

Disturbances of the nervous system are amongst the most important conditions which affect the temperature of the body.

(Apyrexia, Hyperpyrexia. Antipyretics.)

Temperature and pulse.

For every 1°F. increase, the pulse rate is increased 10 beats. (Aiken.)

But bodily temperature may fall and pulse rate rise.

CHAPTER II. –HEAT PRODUCTION.

The source of animal heat is in the potential energy of organic food-stuffs.

This may be converted into heat *directly* by combustion of the food, *i. e.* the transformation of the chemical constituents of the food, C, H, O, N, by oxidation in the tissues ultimately into CO_2, H_2O and urea, (90 p. c.), or

indirectly by mechanical movements, (10 p. c.).

The O necessary is absorbed during respiration, and there is a definite relation between the amount of heat produced and of O consumed.

The amount of heat produced is the same whether the combustion is slow or rapid.

The oxidation of inorganic substances, S, and P, into their acids is also another but trifling source of heat.

The principal mechanical movements concerned in the production of heat are the contractions of voluntary and involuntary muscles, the flow of blood, friction of the joints, etc.

Hence the muscles, secreting glands, and vascular brain, may be regarded as the main *heat-producing tissues*.

Total amount of heat produced.

(Determined by a calorimeter.)

[The *calorie* is that amount of heat necessary to raise the temperature of one gram of water 1°C., (called also a millicalorie or small calorie).

The mechanical unit, or *grammeter*, is the quantity of energy required to raise one gram a height of one meter, and is equal to 424.5 calories.

A *kilocalorie*,, or *kilogramdegree*, = 1000 calories.

A *kilogrammeter* = 1000 grammeters.

By *specific heat* is meant the quantity of heat required to raise the temperature of any substance 1°C; this quantity varying considerably for different substances. If water be taken as 1, the standard of comparison, then the specific heat of the animal body is about 0.8, *i. e.* 0.8 of the quantity of heat necessary to raise the temperature of a certain quantity of water 1 C., will be required for the same weight of animal body.

The specific heat is of importance in calculating the quantity of heat involved in a change of the animal's temperature, *e. g.* should an

animal of 20 kilograms weight have its temperature increased or diminished 0.2, (specific heat being 0.8,) the quantity of heat added or taken from the heat of the body would be = 20 x 0.8 x 0.2 = 3 20 kilogramdegrees.

In estimations of the dissipation of heat the quantity lost in urine and fæces is not generally taken into account, for it is so slight, but the amount imparted to the air in warming the inspired air and in evaporating water from the lungs and skin is of importance.]

Various estimates of the *total amount of heat produced*; can say that about enough is produced to raise 2300 kilos, (2, 2 pounds) of water 1°C., or about 50 pounds of water from freezing to boiling, or 154 pounds of water 56°.5F.

Such an amount of heat would raise the temperature of the human body 3°F. higher, since of the 154 pounds only [illegible] is water and [illegible] is tissue, the specific heat of which is less than that of water. If there were no means of regulating the temperature the normal would in 24 hours be raised to 158°.4F.

Heat Values of foods.

By the calorimeter the potential energy of the food may be converted into heat-units, and the number of these measured.

1 gram of proteid yields about 4937 calories; 1 gram of fat about 9312 calories, and 1 gram of carbohydrate about 4116 calories.

The fatty and carbohydrate foods are as thoroughly burned inside the body as outside of it, though more slowly, but the proteids are imperfectly burned.

Isodynamic foods are such as produce an equal amount of heat. 100 grams of animal albumin (after deducting the heat-units of urea) = 52 grams of fat = 114 grams of starch = 129 grams of dextrose.

CHAPTER III.—HEAT-DISSIPATION.

The loss of heat from the body occurs through various channels, in the urine, fæces, sweat and expired air, also by radiation and conduction from the skin.

(Of 100 calories produced, 2.6 lost in heating food and drink; 2.6 in heating the respired air; 14.7 in evaporation; 80.1 by radiation and conduction. The skin is the most important organ for regulating temperature.)

The chief conditions influencing heat-dissipation by radiation are the following:

- age; the young most, because of greater metabolic activity, and relatively larger body-surface;
- sex; female probably less, on account of greater relative amount of subcutaneous fat;
- species; more in homoiothermal than in poikilothermal, because of the greater activity of heat-production. It varies also according to the medium in which the animal lives, and according to the body-covering;
- quantity of subcutaneous fat, which is a poor conductor of heat and therefore a greater hinderance to its dissipation;
- surrounding medium; water is a better conductor than air; dry air than moist air; cold moist than cold dry air;
- covering of the body; hair, fur. Fur and wool poor conductors; cotton and linen good conductors. Coarser materials afford a better radiating surface. Hygroscopic character of clothing of importance. Weight hinders heat-dissipation. Color.
- internal and external temperature. Abnormal heat-production tends to increase heat-dissipation. (Thermotaxis);
- extent of body surface. In proportion to body-weight smaller animals have larger body-surfaces, therefore heat-dissipation is relatively greater though not absolutely;
- condition of the vascular and respiratory systems: the more active these the greater the heat loss.

Next in importance to radiation is the amount of water evaporated from the skin as sweat; sensible and insensible perspiration.

(Effects of dry and moist atmospheres on the excretion of sweat.)

The co-efficient of radiation (*i.e.* the quantity of heat emitted during a unit of time at a standard temperature from a given area) in an inanimate body remains fixed, because the surface remains virtually unchangeable, but for the living organism it is subject to alterations, depending, besides the above influences, also upon the nervous system, the action of drugs, and upon pathological conditions.

Temperatures, in dry atmospheres of 211° F., 260° F., 350° F., and 400°-600° F. (Chabert, the "fire-king") have been endured for a shor time where heat-dissipation through excessive secretion from th skin was sufficient.

CHAPTER IV.—THERMOTAXIS OR HEAT-REGULATION.

Brought about by the correlation of *thermogenesis* and *thermolysis*.

Thermogenesis depends upon:

thermogenic tissues, thermogenic nerves and thermogenic centres.

Thermogenic tissues are principally the muscles, glands, and brain. (*Vide* Heat-production.)

Thermogenic nerves are hypothetical.

According to some there are specific *efferent* thermogenic fibres: according to others they are the same fibres as those which preserve muscle-tonus: while according to others both heat-production and muscular tone are governed by motor nerves, the effect varying according to the intensity of the impulses.

The existence of *afferent* thermogenic fibres has not been demonstrated.

Thermogenic centres.

There are definite regions of the cerebro-spinal axis which are specifically concerned in thermogenesis: some, when irritated give rise, as a direct result, to increased heat-production, are therefore *thermo-accelerator*: others to diminished, hence *thermo-prohibitory* centres.

Both seem to be associated and governed by a third kind which is distinguished as the *general or automatic centre*.

* Thermo-accelerator centres probably exist in the caudate nucleus, (possibly also in the tuber cinereum and optic thalami), pons and medulla.

Thermo-prohibitory centres have been found in the dog in the region of the sulcus cruciatus and at the junction of the supra-Sylvian and post-Sylvian fissures.

The automatic centres are located in the spinal cord, probably in the anterior cornua.

The automatic centres, affected by impulses coming through various sensory nerves, are apparently not at all influenced by cutaneous impulses caused by changes in external temperature, nor by changes in the temperature of the blood.

The thermo-accelerator and thermo-prohibitory centres are especially affected by cutaneous impressions and by changes in the temperature of the blood, and through their connection with the

general centres these latter are stimulated to increased or diminished activity.

Thermotaxic mechanism.

Heat-regulation is brought about by the reciprocal action of the thermo-accelerator and thermo-prohibitory centres, in connection with the automatic centres, through the influence of cutaneous impulses and the temperature of the blood, in a great measure reflexly.

Disturbance of this reciprocal action results either in hyperpyrexia or in subnormal temperature.

The mechanism includes the cardiac, vaso-motor, respiratory, sweat, and pilo-motor mechanisms, (the last in a subordinate degree in man).

These centres may be stimulated by voluntary actions. (Various means of regulating his temperature made use of by man.)

Abnormal thermotaxis occurs where the mean bodily temperature is maintained at a standard above or below the normal, as in fevers or in animals from which the hair has been shaved.

The centres are here "set," as it were, for a higher or lower temperature of the blood, which they tend to preserve.

Distribution of heat.

Uniformity of temperature is brought about within certain limits by the circulation of the blood which distributes the heat.

Post mortem rise of temperature is common in the case of violent deaths in healthy persons, and in death after convulsions. Due to continued heat-production and diminished heat-dissipation: cellular vitality with somatic death.

Heat is also developed during the changes accompanying the setting in of rigor mortis.

(Temperature sense, *vide* Cutaneous sensibility.)

Relation between food, heat, and mechanical work.

Only about $\frac{1}{6}$ to $\frac{1}{9}$ of the energy of food is expended in muscular work.

Even during violent muscular exercise five times more energy may be expended as heat than as mechanical energy.

Not known whether the chemical energy (oxidation of food substances) is first converted into heat, and part of the heat then transformed into work, or whether the chemical energy is immediately changed into work, or whether there is an intermediate form of energy (electrical ?) other than heat.

SECTION VIII.

SECRETION.

INTRODUCTION.

External secretion is discharged upon a free epithelial surface such as the skin or mucous membrane, while an *internal secretion* is discharged upon the epithelial surface of the blood or lymph cavities. (Liver, thyroid, and pancreas, best known organs furnishing internal secretions, but any organ may give off substances comparable to an internal secretion, even if not of glandular structure, *e. g.* the muscles.)

The term *excretion* may be applied to waste products, or constituents of certain secretions of no further use in the organism.

The type of a secreting surface consists of an epithelium placed upon a basement membrane, while upon the other side of this membrane are blood capillaries and lymph-spaces. The secretion is derived ultimately from the blood and is discharged upon the free surface.

All varieties of arrangement may be classed under *membranes and glands.*

The process of secretion depends upon,

filtration,
osmosis, and
vital activity of the epithelial cells.

Circumstances which influence the function of secretion and the discharge of the product are:

a. variations in the quantity of blood passing through the gland and consequent blood-pressure;
b. variations in the quality of blood supplied;
c. nerve influence, (secretory nerves, and vaso-motor).

The discharge of the secretion is caused by the *vis a tergo*, and by the contraction of the muscular walls of the larger ducts.

The principal secreting tissues and organs are:

serous and synovial membranes;	the liver;
mucous membranes, with glands;	lachrymal glands;
salivary glands and pancreas;	kidneys and skin;
mammary glands;	testes.

MEMBRANES.

I. THE SEROUS MEMBRANES form closed sacs, (except where the opening of the Fallopian tubes communicate with the cavity of the abdomen), lined with pale nucleated epithelium, and containing a small amount of secretion.

a. some line visceral cavities; the arachnoid; pericardium; pleuræ; peritoneum; tunica vaginalis.

b. others, the synovial membranes, line the joints, the sheaths of the tendons and ligaments, or lie between muscles, tendons, or integument and projecting bone; (bursæ mucosæ; synovial bursæ.)

Function principally to prevent friction and facilitate movement.

Serum, is a pale yellow, slightly viscid, alkaline fluid, coagulated by heat: identical with dilute liquor sanguinis; probably separated in great measure by simple transudation.

Quantity in health just enough to lubricate (pleuræ 4–7 oz. peritoneum 1–4 oz.—pericardium 1–3 oz.): excess — dropsy of the sac).

Synovial fluid, a more elaborate product of the cells; denser, extremely viscid, alkaline and with much albumin.

II. THE MUCOUS MEMBRANES line all those cavities which communicate with the exterior, (gastro-intestinal; pulmonary; genito-urinary). Externally they are attached to various other tissues: internally soft and velvety, and extremely vascular.

In all mucous membranes we find a layer of tessellated or columnar epithelium, resting upon a basement membrane, beneath which is a vascular tissue of variable thickness, containing lymphatics and nerves.

These elements may be depressed into glands, or elevated into villi.

The mucous fluid secreted is more or less viscid, greyish, semi-transparent, alkaline, of high specific gravity, = mucus.

It swells considerably when water is added, but does not mix readily.

The microscope reveals epithelium and leucocytes.

Chemically contains mucin,
a little albumin,
salts, (chlorides and phosphates),
water,
fats and extractives in traces.

Varieties according to the membrane from which secreted.

SECRETING GLANDS.

The membrane may be invaginated to form a tube or sac possessing a definite lumen, producing a gland and its duct.

Secreting glands :
- *tubular* ;
  - simple,
  - compound ;
- *racemose*, (saccular).

CHAPTER I.—MAMMARY SECRETION.

MAMMARY GLANDS undoubtedly derived from some of the ordinary skin-glands (homologous with the sweat ; or the sebaceous glands).

Number and position vary much in the different mammalia. In man found in the thoracic region ; normally two in number.

(Anomalies. Supernumerary glands.)

Structure. They are compound alveolar, or conglomerate glands. Lobes ; lobules ; areolar tissue ; fat.

15 to 20 main or *lactiferous ducts*, formed from the union of smaller lobular ducts, and opening separately upon the surface of the nipple.

Sinus lacteus at base of nipple.

Nipple contains areolar and unstriped muscular tissue ; vascular, erectile. On the surface, papillæ, areola, with pigment.

The glands contain around each acinus a network of capillary blood-vessels and lymphatics.

The *nerve supply* is from the supraclavicular, and 2nd, 4th and 6th intercostals.

The glands are rudimentary in childhood, and in the adult male remain in the undeveloped state. (Exceptions.)

In the female as she approaches puberty they increase in size, and during pregnancy are still further developed, becoming harder and more distinctly lobulated, while the areola becomes darker, from increase of pigment, with projecting papillæ, and the veins become darker.

The nipple becomes more prominent, and milk can be squeezed from the orifices of the ducts.

During lactation they retain these characteristics.

In the intervals of lactation they gradually return to their original condition of non-secreting glands.

At the climacteric period all the acini and numerous fine milk ducts degenerate, and the whole gland seems to atrophy.

Milk.

A typical food for the infant. An emulsion.

Human milk always *alkaline:* cow's milk, alkaline or acid; milk of carniverous animals always acid.

Microscopically, milk is seen to consist of a liquid portion or plasma, in which float fine fat-globules.

These latter contain the milk-fat, which consists chiefly of neutral fats, stearin, palmitin, and olein, but contains also a small amount of the fats of butyric and caproic acid as well as traces of other fatty acid compounds, and small amounts of lecithin, cholesterine, and a yellow pigment.

Chemically, the milk-plasma holds in solution proteid and carbohydrate compounds, as well as the necessary inorganic salts.

The *proteids* are casein (a nucleo-albumin),
lact-albumin, resembling the serum-albumin of the blood,
lacto-globulin, similar to paraglobulin of the blood.

The *chief carbohydrate* is the milk-sugar, or lactose.

The *inorganic constituents* of the milk (compounds of K, Na, Ca, Mg, Fe,) found in its ash, resemble quantitatively those found in the body-ash of young animals, while there is a striking difference between the ash of milk and the ash of the maternal blood, proving that they are formed from the blood-serum, not merely by osmosis, but by some selective secretory act.

Chemical composition of milk. (Foster).

	Human.	Cow.
Water	90	87
Solids	10	13
Made up of,—		
fats	2.75	4
proteids	2	4
sugar	5	4.4
salts	.25	.6

The chief salt is calcium phosphate.

Casein, or caseinogen which becomes casein through the action of the calcium phosphate, is the chief nutritive principle.

Quantity and quality of milk.

The quantity of milk secreted (average from 2 to 3 pints) as well as the relative quantity of the several ingredients is extremely variable, depending upon the *individual, and upon diet.* A vegetable diet increases the percentage of sugar, but diminishes that of the other constituents and also the total quantity of milk.

A rich meat diet increases both the total quantity and the percentage of fats and proteids.

Large quantities of fluids increase the total quantity; (coffee lessens.)

The proportion of albumin increases as the sugar decreases, and the fat remains the same as the period of lactation advances.

The oftener the breasts are emptied the richer in casein the milk. The last milk drawn always richer in fats.

The evening milk richer in fat than the morning milk.

The general amount of solid constituents falls up to the age of thirty years, then gradually gains until thirty-five, after which the milk becomes decidedly thinner.

The mental state of the nurse affects both quantity and quality of the milk, indicating that the gland is under the regulating control of the central nervous system (although essentially an automatic organ,) either through secretory or vaso-motor fibres.

Influence of drugs.

Of drugs Jaborandi is said to be the nearest approach to a galactogue, but its action is temporary.

Atrophine is a true anti-galactogue; KI is similar in its action.

(Anomalies of mammary secretion.)

Colustrum is the fluid secreted in the first days after parturition, differing from true milk in containing a larger amount of solid matter, and showing, under the microscope, *colustrum corpuscles*, which seem to be wandering cells that have undergone complete fatty degeneration. It acts as a laxative.

Much lact-albumin, little casein, more sugar, salts and especially fats.

CHAPTER II.—SECRETION OF URINE.

URINARY APPARATUS: kidneys, ureters, bladder.

Kidneys.

Anatomy. The kidney is a compound tubular gland. The uriniferous tubules may be roughly separated into a secreting part

comprising the capsule, convoluted tubes, and loop of Henle; and a collecting part, the so-called straight collecting tubes, the epithelium of which has no secretory function.

Each Malpighian corpuscle consists of a tuft of blood-vessels, the glomerulus, made up of numerous twisted non-anastomosing capillaries from a small afferent artery. A single efferent vein is formed, of a smaller diameter than the afferent artery. Hence in the glomerulus there must be a greatly diminished blood velocity, and increased blood pressure.

The glomerulus lies in a double-walled capsule. The inner wall is closely adherent to the capillaries; is called the glomerular epithelium, and is composed of flattened endothelial-like cells,

The outer layer, is composed of cuboidal or cylindrical epithelial cells, protoplasmic, granular, with the general appearance of active secreting structures.

(*Vide*, for further particulars, Histology.)

Blood supply of the kidneys.

The kidney is a very vascular organ when in strong functional activity. (In a minute's time, under action of diuretics, an amount of blood flows through the kidney equal to the weight of the organ; this is from 4 to 19 times as great as occurs in other organs in the systemic circulation. Oncometer.)

In the kidney the blood passes through two sets of capillaries before emerging by the renal vein.

Nerve supply. Richly supplied with vaso-motor nerves: the vaso-constrictor nerves, emerging from the spinal cord in the lower thoracic spinal nerves, (tenth to thirteenth in the dog), pass through the sympathetic system, (renal plexus), and reach the organ with the blood-vessels, as non-medullated fibres.

Vaso-dilator nerves emerge from the spinal cord mainly in the anterior roots of the 11th, 12th and 13th spinal nerves.

This local nervous mechanism is probably reflexly stimulated, causing increased or diminished secretion by corresponding alterations in the blood supply and blood-pressure.

Secretion of Urine.

Heidenhain-Bowman's theory is the one generally accepted, that the glomeruli secrete the water and inorganic salts, by the special activity of the epithelial cells, as well as by simple filtration, and that the urea and related bodies are eliminated through the activity of the epithelial cells in the convoluted tubules.

The functional activity of the kidneys depends upon the blood supply; the amount filtered off depends upon the blood-pressure in the glomeruli, the greater the pressure the greater will be the flow of urine.

Quantity, therefore varies: average amount secreted by an adult 2 to 3 pints per day: (1000–1880 c.c.)

(Heart's action: total contents of vascular system; diminution of the capacity of the vascular system. Drugs—diuretics—which increase the general or local pressure, etc.)

Bladder: *anatomy;* serous, muscular, and mucous coats; ureters. Urethra.

Micturition.

The urine is secreted continuously by the kidneys; is carried to the bladder through the ureters, and then, at intervals, is ejected through the urethra by the act of micturition.

A rhythmic peristaltic contraction of the ureters, either spontaneous or originated by the presence of urine in their upper or kidney portions, forces the urine with a velocity of about 2c or 30 mm per second, in gentle spirts into the bladder.

The urine accumulates in the bladder to a certain extent.

It is prevented from escaping at first by the elasticity of the parts at the urethral orifice, aided perhaps by the tonic contraction of the internal sphincter.

Greater accumulation brings into play the contraction of the external sphincter, reflexly at first, then voluntarily.

Back-flow into the ureters is prevented by the oblique course of the ureters through the walls of the bladder.

At a certain point of fulness a conscious sensation arises, and a desire to micturate. This takes place by a strong contraction of the bladder, either purely reflex, or assisted by voluntary effort, with a simultaneous relaxation of the external sphincter.

The force of contraction is considerable, and may be assisted by contraction of the walls of the abdomen, with glottis closed so as to keep the diaphragm fixed, as in vomiting and defæcation.

(The last portion of the urine escaping into the urethra is ejected, in the male, in spirts by the rhythmic contractions of the bulbo-cavernous muscle.)

Nervous mechanism. This consists essentially of ganglionic centres in the lumbar enlargement of the cord, and two sets of nerve fibres, to and from these centres. One set connects with the urinary organs,

and the other with the cerebral hemispheres, so that the centre may act reflexly or be controlled by the will.

(Reflex action in infants. *Eneuresis*, from urine, worms, dentition, emotional disturbances, etc.—*Retention* vs. *suppression*—*Strangury*.)

(*Incontinence*, from disturbance of the mechanism of micturition from disease, especially of the spinal cord.)

URINE.

The urine is a transparent, straw-colored liquid, with peculiar aromatic odor, a bitterish taste, slightly acid reaction.

Specific gravity from 1015 to 1025, average 1020.

The *transparency* may be interfered with by: mucus, by earthy phosphates of lime and magnesium (increased by heat, caused to disappear by any acid), the mixed urates of Na, K, Ca, and Mg (disappearing when urine becomes cold), pus, or fat.

Its *fluidity* lessened by large quantities of albumin, sugar, mucus or pus, or fat.

The *color* may vary normally with the proportionate quantity of contained water, pathologically from increase or decrease of normal coloring matters, from presence of abnormal coloring matters (bile pigments, blood, vegetable matters eliminated).

The *characteristic odor* due to minute quantities of phenylic, taurylic, and damaluric acids: may be changed by decomposition, or by substances eliminated by the kidneys, or by disease of the bladder or kidney.

The *reaction* of normal urine is acid, depending upon acid sodic-phosphate; (of carniverous animals decidedly acid, of herbivorous, alkaline). Acidity is increased after the use of acids, after muscular exercise, in the morning, during hunger; decreased or changed to alkaline, by the use of caustic alkalies, after a meal, by profuse sweating, and in anæmia.

The *specific gravity* varies greatly. (Urinometer.) Normal range between 1015 and 1020; average 1020. After copious drinking, abstinence from proteid food, and in cool weather it may fall as low as 1005. After prolonged abstinence from liquids, much animal food, and very active sweating, it may reach 1040 without being pathological. In infants it is 1003 to 1006. Pathologically it is increased in diabetes mellitus (1050?), (exceptions occur): in first stage of acute fevers; in first stage of acute Bright's disease (from presence of blood).

It is diminished pathologically in hysteria, in all forms of Bright's disease except as above.

The *chemical composition* of the urine is very complex. On an average it may be said to contain about 4 p. c. of solids, and 96 p. c. of water. (Haeser's co-efficient.)

The most important of the solids are:

Urea, $(NH_2)_2CO$ the most essential and most abundant, about 2 p. c. of the urine. It is regarded as the chief end-product of the oxidation of the nitrogenous matter in the body, so that the amount per diem gives us an estimate of the nitrogenous metabolism. (1 gram of proteid will yield $\frac{1}{3}$ gram of urea.)

Chemically it is carbamide, isomeric with ammonium cyanate, from which it was first artificially prepared.

(Readily soluble in alcohol and water, insoluble in ether.)

With nitrous acid or sodium hypobromite it is decomposed with brisk effervescence of gases, N and CO_2.

With nitric and oxalic acids urea forms sparingly soluble salts.

The *amount* eliminated in 24 hours is about 500 grains (35 grams). This varies—

1. With the diet. Increased by much proteid food; diminished by fasting.

2. With the quantity of urine secreted. Increased amount of urine accompanied by increased amount of urea. NaCl increases the water and also the amount of urea.

3. With age. Relatively greater amount in childhood.

4. With sex; males more than females.

5. With disease.

In most febrile conditions an increase; in disease of the liver often markedly decreased. In diabetes, if consumption of food very great, the daily excretion of urea may reach nearly 4 ounces (100 grams).

(*Preparation from urine*. Evaporate urine to one-sixth its bulk, add excess of nitric acid and let stand in cool place for the yellow crystals of impure nitrate of urea to be precipitated. Filter and dry these; dissolve in boiling water; mix with charcoal, and filter while hot. On cooling, the filtrate deposits colorless crystals of nitrate of urea. The precipitate is dissolved in boiling water and barium carbonate added as long as effervescence takes place, barium nitrate and urea being produced. This is evaporated to dryness and the urea extracted with absolute alcohol, which on evaporation leaves crystals of pure urea.)

Estimation. volumetrically by the method of Liebig which depends upon the power of mercuric nitrate to give a precipitate. A readier and more accurate method is with a solution of sodium hypobromite containing an excess of caustic soda. Amount determined by the amount of free N evolved, which is measured in a graduated tube. Doremus apparatus.

Urea occurs not only in the urine but is found in the blood (1 : 10,000), lymph, chyle, (1 : 500), liver, lymph glands, spleen, lungs, brain, eye, bile, saliva, amniotic fluid, and in the sweat.

Seat of urea formation has been proved not to be in the kidneys. It is brought to the kidneys in the blood for elimination, the cells of the convoluted tubules being especially adapted for taking up this material and transmitting it through their substance to the lumen of the tubules.

It is produced mainly in the liver, although the presence of urea in the urine after the removal of the liver shows that other organs, not known which, are capable of producing it as well.

Urea arises from proteids of food or tissue waste, by a process of hydrolysis and oxidation, with the formation eventually of ammonia compounds, most probably the ammonium salts of carbamic acid which are then conveyed to the liver and there changed into urea.

Uric acid and xanthin bodies.

Uric acid ($C_5H_4N_4O_3$) is found constantly in relatively small quantities in human urine : (entirely absent in cat tribe).

Normal *quantity* in 24 hours varies from 0.2 to 1 gram. (5–15 grs.) In the urine of birds and reptiles it forms the chief nitrogenous constituent, and in them is mainly formed in the liver, probably also in man. Increased in fevers, in leucæmia, in cirrhotic liver, catarrhal condition of the stomach and intestinal tract after abuse of alcohol.

In gout deposited as urate of soda in joints. Decreased by much water, after large doses of quinine, caffein, KI, common salt, sodic and lithic carbonates, etc.

It is readily converted into urea by oxidation outside of the body.

(*Murexid test :* urine heated and cautiously evaporated with nitric acid in a flat capsule ; a yellow residue which gives a striking purple with a drop of ammonia, and this changes to violet on the addition of potash.)

The most common form in which it is deposited in the urine is that of a brownish or yellowish-red powdery substance, consisting of granules of ammonium or sodium urates.

"Brick-dust" sediment is the acid sodium urate.

Xanthin group of nitrogenous substances, is closely related to uric acid, and comprises xanthin, hypoxanthin, guanin, and adenin. Found only in minute quantities in the urine; in greater quantity in muscle, and are therefore present in meat extracts. (Theobromin, and caffein are closely related to the xanthin bodies.)

Creatinine ($C_4H_7N_3O$), a crystalline nitrogenous body always found in the urine and derived from *creatin*, ($C_4H_9N_3O$), (a constant constituent of muscle) by the loss of a molecule of water.

About 15 grs. (1 gram) excreted in 24 hours; increased by an increase in the nitrogenous constituents of the food.

Hippuric acid, ($C_9H_9NO_3$), is a normal constituent of human urine; in small quantities, (0.7 gram in 24 hours); increased by vegetable diet.

(Probably derived from a synthesis of glycol, or glycocin, and benzoic acid, taking place in the kidneys. Some is supposed to result from the proteid putrefaction which occurs in the large intestines.)

(*Conjugated sulphates*, of phenol, cresol, indol, and skatol. These latter substances, formed in the intestines during the proteid decomposition, are injurious, but, in passing through the liver, they are synthetically combined with sulphuric acid, making the so-called "conjugated sulphates", which are harmless, and which are excreted by the kidneys.)

Coloring matter.

Urobilin is the normal coloring matter of the urine; an outcome of the biliary pigments, and therefore derived from hæmatin of the blood, probably = hydrobilirubin.

Urochrome, probably an impure urobilin.

Inorganic salts.

The urine is the great outlet for all inorganic salts.

They arise partly from the salts ingested with the food, and are partly formed in the destructive metabolism taking place in the body.

Sodium chloride ($NaCl$), occurs in the largest quantity, averaging about half an ounce (15 grams) per diem. It depends largely upon the quantity taken with the food, and falls during starvation, but does not entirely disappear. If absolutely no $NaCl$ be taken with the food the quantity excreted diminishes greatly, and albumin appears in the urine about the third day.

The amount eliminated follows closely the quantity of urea excreted.

In some diseases the quantity of NaCl is greatly diminished, *e. g* in pneumonia.

(*Test for chlorides;* Nitric acid and then Arg. nitr., which gives a curdy precipitate of chloride of silver.)

(Chlorides of K, Ca, and Mg also occur.)

Phosphates occur in combination with Ca and Mg, but chiefly as the acid phosphates of K and Na, to which latter the acid reaction of the urine is due.

They come in part from the destruction of phosphorus-containing tissues in the body (nervous tissue), but chiefly from the phosphates of the food.

Quantity about 60 grains (3 to 4 grams) excreted daily; increased after meals, mental work, in fevers, after taking lactic acid, morphia, chloral and chloroform.

Diminished during pregnancy, after ether and alcohol, and in inflammation of the kidney. Heat causes them to disappear; dissolved by nitric or acetic acid.

Sulphates. Nearly 40 grains (2 to 3 grams) of sulphuric acid are gotten rid of in the urine daily, as sulphates of alkalies, and conjugated with organic substances (*vide supra*). S is a constant element of the proteid molecule, and the quantity of it eliminated in the urine may be used, as in the case of N to determine the total destruction of proteid within a given period.

Iron is always present in traces in the urine.

Gases, CO_2 (10 vols. p. c.), N, and O are also found in the urine.

Abnormal constituents.

Albumin, from increased blood-pressure in the renal vessels, from excess of albumin in the blood, from a watery condition of the blood, from total abstinence from NaCl, from destruction of the epithelium of the urinary tubes.

Tests for Albumin in the Urine. (*Cf.* Chemical reactions of Proteids. p. 7.)

Heat.

Heat and nitric acid. (Purdy's: add to urine a little of a filtered saturated solution of NaCl; acidify with acetic acid; boil the upper inch.)

Heller's cold nitric acid, underlying the suspected urine.

Picric acid.

Tanret's fluid: (potassium iodide, 3.32 grams;
bichloride of mercury, 1.35 grams;
acetic acid, 20 c.c.;
distilled water to 100 c.c.)

Esbach's Albuminometer.
(Fluid: picric acid; 10 grams;
citric acid, 20 grams;
water to one litre.)

Acetic acid and potassium ferrocyanide give a flocculent white precipitate.

Sugar. Normally only the merest trace occurs in the urine, although there is constantly a certain quantity in the blood. Any great disturbance of the circulation of the liver gives rise to an increase of sugar in the blood, which normally contains only about 1 p. c., and when the amount reaches 3 p. c. it appears in the urine. (Glycosuria.)

We find it in large quantities in diabetes; after injury to a certain part of the brain (diabetic centre, in the floor of the 4th ventricle); after total extirpation of the pancreas, after poisoning by curare, carbonic oxide, and nitrite of amyl.

Tests for sugar in the urine. (*Cf.* Tests for Glucoses, p. 8.)
Haines;
By fermentation;
Trommer's test;
Fehling's solution.

Other substances found at times are *ferments, peptones, chyle* (chyluria), *blood, bile acids* and *pigments*, various *salts* taken as medicine, *fats, casts,* and *micro-organisms* (typhoid bacilli).

Acetone may occur normally in the blood and urine; it is found in large quantities in patients suffering from an abnormal decomposition of organized proteid, *e. g.* in carcinoma, inanition, etc.

Test for peptones, and hemi-albumose.

Acidulate slightly with acetic acid; saturate with ammonium sulphate, and filter;

Tanret's fluid will cause a white precipitate if peptones are present.

Urinary Calculi.

Arise from concretions of ingredients of the urine which are difficult of solution, especially if there exists any small foreign body to serve as a nucleus. May form in the tubes or pelvic recesses of the kidney, or in the bladder. Chief materials are uric acid, ammonium urate, calcium oxâlate and carbonate, ammonio-magnesium phosphate, etc.

CHAPTER III.—SKIN.

The skin serves as an external covering, whereby the inner parts are protected, at the same time that by the nerve-fibres of pressure, temperature, and pain, distributed over its surface, reflexes are effected which keep the body adapted to changes in its environment. (*Vide* Touch.)

It plays an important part in the regulation of temperature, (*q. v.*).

(Varnishing the skin kills by excessive loss of heat).

It is an important organ of secretion and excretion, through its glands, sebaceous and sweat-glands, and the mammary glands, (*q. v.*).

Structure.

From 3.3 to 2.7 mm. in thickness.

Consists of the *chorium, derma, or cutis vera*, the deeper vascular tissue, with the papillæ, hair follicles and sudoriferous and sebaceous glands;

and the *cuticle or epidermis*, with several layers of cells.

The so-called appendages of the skin, the *hair* and *nails*, are modifications of the epidermis.

The *pigment* of the skin is contained in the deepest layer of the epidermis, the rete mucosum.

(Exfoliation. Callosities.)

Glands of the skin.

Sudoriferous, or *sweat glands:* distributed more or less thickly over whole surface of the body, except on prepuce and glans penis. They are tubular glands embedded in the subcutaneous adipose tissue.

Sweat, or *perspiration*, is a colorless liquid, with a peculiar odor (from volatile fatty acids), and a salty taste (from NaCl). Sp. gr. 1004. Usually acid reaction (from fatty acids from decomposition of sebum), but when profuse, may be neutral or alkaline.

Quantity varies greatly ; average 1½ to 2 pints (700 to 900 grams). Its water is inversely proportional to that secreted by the kidneys.

Increased by increased temperature, very watery condition of the blood, cardiac and muscular activity, certain drugs (sudorifics, diaphoretics).

Chemically consists of water, inorganic salts (chiefly NaCl) fats, fatty acids, cholesterine, and urea.

Urea a constant but unimportant constituent: amount may be markedly increased under pathological conditions.

The water-secretion is of importance in maintaining the water-equilibrium of the blood and tissues, still more in controlling the heat-loss from the skin.

Nerves ; vaso-motor, and secretory. Sweat centre in the medulla with subordinate ones in the cord.

(In localized vaso-motor paralysis sweating sometimes takes place. Section of cervical sympathetic produces copious sweating of the same side of the head.)

Sebaceous glands, usually in connection with the hairs, also found all over the body except upon the palms of the hands and soles of the feet. They are racemose glands in the true skin.

The secretion, *sebum*, is an oily, semi-liquid material, consisting chemically, of water, salts, albumin and epithelium, fats and fatty acids.

Function: to soften and lubricate the skin, render the hair pliable, and prevent too great loss of water through the skin.

(Lanoline, agnine, etc.)
(Vernix caseosa. Smegma præputialis.)
(Cerumen).

Pathological variations in the secretion of the skin.

anidrosis ; hyperidrosis ;
hæmatoidrosis, chromidrosis, bromidrosis ;
Seborrhœa ; comedones.

Cutaneous respiration.

Excretion of CO_2 by the skin is very slight in mammals, about $\frac{1}{150}$ to $\frac{1}{200}$ of the quantity given off through the lungs.

In some animals, *e. g.* the frog, the respiratory function of the skin is important.

The absorptive function of the skin.

The power of absorbing liquids by the skin with an uninjured epidermis, is very small, but present.

Assisted by rubbing, even metallic substances can produce their characteristic effects when applied outwardly.

Removal of fat by alcohol, ether or chloroform aids absorption.

(Emesis, cartharsis, narcotism, ptyalism, produced by external application of drugs).

(Galvanic condition.)

Appendages of the skin.

Hair, a modification of the epidermis, found on nearly every part of the surface of the body. (Lanugo, the down-like hair found on the fœtus about the 5th month.)

The *shaft* of the hair is fastened by its root in a depression in the skin, the *hair follicle*, which passes obliquely through the skin into the subcutaneous tissue.

The hair is formed by the production and growth of epidermal cells from the surface of the *papilla*, a projection of the true skin at the bottom of the follicle.

Pigment is in the cortical part of the shaft.

(Grey hair. Cutis anserina.)

Function of the hair to protect from heat and cold and foreign bodies.

(Arrector pili muscles.)

Nails grow from the papillæ of the chorium under the nail, the matrix. (Lunule.)

Function protective, and to assist in delicacy of touch.

SECTION IX.

MUSCULAR SYSTEM.

(Comparative anatomy, from the budding out of the proto-plasmic mass of the ameba to the complicated muscular system as found on the higher animals.) .

The various forms of contratile tissue depend upon the requirements of speed and duration of exertion.

CHAPTER I.—MUSCULAR TISSUE.

Of the higher mammals :

I. PLAIN NON-STRIATED, *or involuntary.*

II. STRIATED *or voluntary.*

I. PLAIN, *smooth, non striated,* found chiefly in the walls of hollow organs.

Consists of pale, elongated, spindle-shaped flattened, homogeneous cells, with a single rod-shaped nucleus. Size varies from $\frac{1}{4000}$ to $\frac{1}{3000}$ in. in breadth, and of varying length.

(Endomysium ; perimysium.)

Blood-vessels and lymphatics numerous.

Nerves form a ground-plexus, and inter-muscular plexus, with terminal filaments in the nucleus ; from the sympathetic system.

II. STRIATED, *striped, skeletal, voluntary.*

Distribution.

Structure. The muscle fibre, which is the unit of which the anatomical muscle is made up,

i. is surrounded by a structureless membrane, the *sarcolemma* ;

ii. the contents of the muscle fibre consists of two functionally different substances,

a.—a *contractile substance,* arranged in longitudinal fibrillæ (sarcostyles) embedded in an interfibrillar matter (sarcoplasma), and

b.—*an interstitial, non-contractile,* probably nutritive material of more fluid nature.

Length and breadth vary greatly in different situations; maximum length $1\frac{1}{2}$ to 2 in., breadth, average $\frac{1}{500}$ in.

(*Histology*. Various theories.)

Blood supply. Each muscle usually receives several branches of different arteries; the arteries and veins lying usually in the perimysium and the capillaries in the endomysium.

The *nerves* are from the cerebro-spinal system, terminating in motorial-end-plates, after having formed ground and intermediary plexuses.

Sensory fibres, the channels for muscular sensibility, seem distributed on the outer surface of the sarcolemma, where they form a branched plexus and wind around the muscular fibres.

The *Heart muscle* differs from both kinds of muscle; it is striped, but is made up of truncated oblong branching cells, with a central nucleus, and no distinct sheath of sarcolemma.

Its action is peculiarly independent of the higher nerve-centres being quite involuntary, and characterized by a definite periodicity, and is incapable of tetanus.

Chemistry of Muscle.

Muscle contains about 75 parts water, and 25 parts solids; of these latter, nearly 21 are proteids, the remaining parts fats, extractives, and salts.

Chemistry of living muscle not definitely known. The death of the muscle ordinarily associated with a peculiar chemical change known as *rigor mortis*.

Rigor mortis.—The muscle loses its vital properties; becomes opaque; and by a gradual contraction, with development of heat and acidity, stiff and firm to the touch; less elastic and less extensible.

Conditions influencing the development of rigor mortis.

The muscle fibres are affected one after the other, in the different parts of the body in a regular order, from above downward, jaw, neck, trunk, arms and legs.

Time required, variable, determined in part by the nature of the muscle, its condition at death, and the temperature to which it is subjected.

Muscles of warm-blooded animals pass into rigor more quickly than those of cold-blooded; the pale muscles more quickly than the red; the flexors than the extensors.

In muscles, strong and vigorous at the moment of somatic death, it comes on slowly, in enfeebled or fatigued, rapidly.

Cold delays and warmth hastens.

In warm-blooded animals from 10 minutes to, some say, as late as 18 hours.

Lasts from 1 to 6 days. The earlier it appears, the sooner it passes off.

(Muscular contractions after death. Somatic death: cellular death.)

Cause of rigor mortis.

Probably due to the coagulation of the myosinogen of the muscle-plasma into myosin, a proteid body, (globulin), resulting from the chemical action of the myosin ferment, which is thought to be formed at the death of the muscle.

(*Cf.* fibrinogen, and fibrin).

By mincing a muscle in rigor mortis, and expressing the fluid, we obtain the *muscle-serum.*

The clot has been found to contain
- paramyosinogen, and myosinogen.

The serum, contains:
- myo-globulin,
- myo-albumin, and
- myo-albumose, distinguished by their solubilities in neutral salt solutions of various strengths.

The pigments are hæmoglobin, and one special to muscle myo hæmatin; both probably respiratory in function.

The ferments: a proteolytic,
- an amylolytic, and
- a muscle ferment, as above.

Nitrogenous extractives:
- creatinin, and xanthin bodies,
- traces of urea,
- uric, and inositic acids,
- taurin and glycocoll; — waste products of the partial oxidation of the proteids of muscle during katabolic processes which take place even in resting muscle.

Non-nitrogenous bodies:
- fats, normally very little;
- glycogen, stored up in variable quantity as a source of energy;
- glucose, small quantity, source of glycogen and energy.

Inorganic constituents:

chiefly potassium phosphate;

Na, Mg, Ca, and small quantities of iron also found.

Gases:

CO_2, much increased by muscular work;

N, in small quantity;

No free O.

CHAPTER II.—PHYSIOLOGY OF MUSCLE.

Muscle possesses:

I. Irritability, *i.e.* the property of reacting both physically and chemically, to irritants or stimuli.

Stimuli may be mechanical, chemical, thermal, electrical or nervous. The normal physiological stimulus is developed within the nervous mechanism of the body, as a result of the activity of the nerve-protoplasm.

(Effects of irritants best studied upon the nerves and muscles of cold-blooded animals. Effects on nerves and muscles can be studied separately. Curare paralyzes the nerve endings.)

But muscle protoplasm possesses an independent irritability.

The most useful irritant for purposes of study is the electric current.

(Galvani. Volta. Daniell cell.

Induction apparatus; Du Bois-Raymond's. Myograph, myogram.)

A constant current of exactly even intensity causes no contraction, but only at the moment of turning on or off, or when the intensity is increased or decreased.

The *making-contraction* starts from the *kathode*, and the *breaking-contraction* from the *anode*.

The making, kathodal, or closing contractions are stronger than the breaking, anodic or opening contractions. (The opposite in disease gives bad prognosis.)

The stronger the electric current, the greater its irritating effect.

The greater the density of the stream, the greater the irritating effect.

Unstriated muscle requires that the current should last from ¼ second to 3 seconds to produce maximal contractions; striated, 0.001.

The galvanometer shows in a muscle removed from the body, electrical currents called "*currents of rest*." Probably due to changes

produced by injury. On contraction these currents are abolished by so-called "*currents of action*" producing the "*negative variation.*"

The irritability of muscle is increased by moderate stretching, and destroyed if it be excessive: (over-flexion or extension in testing knee-jerk and ankle clonus).

Sudden and extreme changes in temperature increase the irritability: (*rigor caloris*, from gradual heating, differs from contraction from an irritant.

The only solutions of drugs or chemicals which fail to alter the irritability of muscle are those which closely resemble serum and lymph. The percentage of salts contained seems to be the important factor. If the change in the chemical condition be a rapid one, it is usually accompanied by the phenomena of excitation; if more gradual, the irritability alone is altered.

(Veratria, eserin, digitalis, alcohol, chloroform, ether, sublimate, mineral acids, except phosphoric, many organic acids, free alkalies, most salts of heavy metals destroy irritability. CO_2, acid potassium phosphate, and lactic acid lessen it.

Neutral K salts, concentrated, kill after exciting. Many gases and fumes chemically irritate and kill.)

Late experiments have shown that even the deci-normal, or physiological solution of NaCl, (6 parts per 1000) (0.6 p. c.) if long applied, at first increases, then decreases the irritability of muscle.

Influences which tend to maintain the physiological irritability of muscle.

Normal blood-supply, to furnish energy-holding materials, and O, and to remove injurious waste material and surplus energy.

Connection with the central nervous system. Separation of this causes a gradual alteration in the irritability of the muscle. At the end of a fortnight it is lessened for all forms of stimuli: from this time on, for mechanical irritants, but for direct battery currents it begins to increase; while it decreases for induction shocks. (Reaction of degeneration). The increase reaches its maximum by the end of the seventh week, and from that time response to all stimuli weakens until all excitability is lost by the end of the seventh or eighth month.

Functional use if not excessive. Fatigue exhausts by using up energy-holding compounds, and accumulating waste material.

If muscles are forced to work after fatigue has developed the time of recovery is prolonged out of all proportion to the extra work accomplished. The exciting nerve cells give out sooner than the

muscles, but recover more rapidly. Whether the nerve fibre fatigues is not yet determined.

Disuse results in loss of strength ; use is the most effective means of increasing not only the strength, but also the endurance of the muscle.

(Rest-cure. Massage ; passive motion. Athletic training.)

II. Conductivity, is that property of protoplasm by virtue of which a condition of activity aroused in one portion of the substance by the action of a stimulus of any kind may be transmitted to any other portion.

In the skeletal muscles each separate fibre is physiologically independent of the rest and is supplied by a separate nerve fibre, for the sarcolemma prevents continuity and even contiguity of muscle tissue, and there is no cross-conduction from fiber to fibre. The muscle of the heart is supposed to allow of conduction from cell to cell, without the intervention of nerves, having no sarcolemma.

The motorial end-plates are the means by which the nervous impulse is conveyed to muscle fibres, and correspond to the brush-like endings of nerve fibres in the immediate vicinity of the nerve cells which they are intended to stimulate.

Conduction may take place in both directions in a muscle.

The rate of conduction, has been found by various recording mechanisms, to be about 3 meters per second in the frog's muscle. It varies considerably in different animals, and in different muscles of the same animal.

Influences which alter the rate and strength of conduction.

Death process. In a dying muscle the rate of conduction as well as the rapidity of contraction is lessened.

Pressure and *temperature* alter the conduction of muscles through their influence upon the conduction of the nerves supplying them.

Chemicals and drugs greatly influence the conductivity, as they do the irritability, but their effects are not always the same. Thus the direct application of alcohol, ether, etc. may destroy the conductivity without greatly lessening the irritability, while CO_2 may destroy the irritability, leaving the conductivity unimpaired.

Constant battery currents, if strong, completely destroy the conductivity.

III. Contractility is that property of protoplasm by virtue of

which the cell is able to change its form, when irritated, or when excited by changes occurring within itself.

The change of form does not involve a change of size.

When a muscle is excited to action, energy is liberated through a chemical change of certain constituents of the muscle substance, and this energy, in some unknown way, causes a rearrangement of the finest particles of the muscle-substance and the consequent change in form peculiar to the contracted state. When the irritation ceases and relaxation takes place, there is a sudden return of the muscle-substance to the position of rest, due to its elastic recoil.

IV. Elasticity of muscle, and **Extensibility** are of great importance.

Elasticity is that property by virtue of which it tends to preserve its normal form.

The elasticity of living muscle is more perfect than that of dead, and preserves the tension of the muscles under all ordinary circumstances. The muscles are attached to the bones under elastic tension, as is shown by the separation of the ends when a muscle is cut. This is favorable to prompt, economic action, as it takes up the slack, and ensures instant response to stimulus.

Extensibility protects against the danger of rupture of muscle-fibres and ligaments and injury to joints on sudden contraction or strain.

A given weight will stretch a contracted muscle more than a passive one, but the return to its normal length is not so complete, that is, its extensibility is increased, but its elasticity decreased; hence if stimulation be applied to an over-weighted muscle it is elongated instead of contracted.

A simple muscle contraction.

(Myograph.—Chronograph.)

A myogram of a single contraction shows

a latent period = $\frac{1}{100}$ second,

a rising curve = $\frac{4}{100}$ second,

a falling curve = $\frac{5}{100}$ second, the total time occupying about $\frac{1}{10}$ second.

The latent period is now supposed to be taken up by electrical changes in the muscle protoplasm, which require time for their manifestation, although it becomes active at the instant it is stimulated.

(electrical latent period = 0.0025 second; mechanical latent period = 0.004 second; and the latent period of the end-plates = 0.002—0.003 second.)

Influences which affect the activity and character of the contraction.

Character of the muscle, more particularly its function.

Unstriped muscles of the walls of the intestines and blood-vessels, which require to remain in a state of continued contraction for considerable periods, and do not alter rapidly, are remarkable for the slowness and duration of their contractions.

The heart muscle has a strong, not too rapid, slightly prolonged contraction, peculiar to itself, and adapted to its function.

The skeletal mescles appear to have different rates of contraction and relaxation, according to the weight and function of the parts to be moved.

Tension or weight applied to the muscle, prolongs the latent period, either lessons the rate of contraction and decreases its amount, or, if the weight be not too great, it may increase the rate and the amount by the suddenly imparted energy.

The *rate of excitation* and the length of the *interval of rest* has a great effect upon the condition of the muscle and its capacity to work.

The first effect of action is to lessen irritability; the anabolic changes are too slow to compensate for katabolic changes, and each of the first few contractions leaves behind it a fatigue-effect, indicated on the myogram by the decline in the height of the first three or four contractions, called the "*introductory contractions.*" Soon activity heightens anabolism, and increases irritability, as shown in the growth of the height of the succeeding contractions, called the "*stair case contractions.*" ("Limbering up to work.")

Fatigue causes a decline in the height of the contractions, and a line connecting their summits, "*the curve of fatigue,*" may be a straight line if the failure in anabolism is very regular in its manifestations.

Muscle-tetanus is the result of excitation at short intervals, so that the effect of each contraction shall influence the one to follow, by increasing the irritability, by a summation of excitation-effects, and by support by the contracting muscle to itself by contracture.

The number of stimuli required per second to produce tetanus depends largely upon the nature of the muscle. The heart muscle cannot be tetanized.

All normal physiological contractions are supposed to be tetani, although this is not yet proved.

Accompaniments of muscular contraction.

I. Change of form. The muscle becomes shorter, rounder, harder, and apparently tougher.

II. Change in temperature. (Thermopile.) Energy leaves the body as mechanical energy when work is done; most of the energy liberated within the body leaves it as heat; even during violent muscular exercise five times or more energy may be expended as heat than as mechanical energy. Up to a certain point, the greater the weight, the greater the heat produced, but the liberation of heat reaches its maximum and declines sooner than the amount of work: as the muscle is weakened by fatigue, the heat-production lessens sooner than the work.

III. Production of a distinct sound, first observed by Wollaston, caused by vibration of its finest particles.

IV. Chemical changes,

- a. The reaction becomes acid, from development of sarcolactic acid.
- b. The muscle gives out more CO_2, and consumes more O.
- c. The amount of glycogen and glucose diminishes, and inosite makes it appearance.

V. Electrical changes. The "currents of rest" or "natural muscle currents" (occurring in a muscle at rest when injured), are reversed, ("negative variation").

Muscle-tonus. During waking hours the central nerve cells are continually receiving weak nerve impulses from the sensory organs all over the body, which are transmitted to the spinal cord, causing an increased irritability and excitation of the motor nerve cells. These continually send delicate motor stimuli to the muscles, causing them to keep in a state of slight but continued contraction, which gives the tension peculiar to waking hours, and which is called muscle-tonus. (Probably same true of smooth muscles of viscera and blood-vessels.)

Muscle-tonus, like every form of muscular contraction, is the result of chemical change, and the liberation of energy, mostly heat.

(Theory of a *reflex chemical tonus*, independent of contraction, implying the existence of special nervous mechanism for exciting chemical changes in the muscles which result in the liberation of energy as heat, heat-centres).

Actions of Voluntary Muscles.

(Anatomy. Various forms of articulations, sutures, symphyses, syndesmoses, by joints.)

The greater part of the voluntary muscles act as sources of power for moving levers, the latter being the various bones to which they are attached.

All three forms of levers are represented in the body.

Levers of the first order, P(ower) F(ulcrum) W(eight). The raising of a body from a stooping position by means of muscles attached to the tuberosities of the ischia.—The extension of the forearm in driving a nail, triceps acting on the olecranon is the power, trochlea the fulcrum, the hammer, hand and forearm the weight.

Levers of the second order, (P. W. F.). The raising of the body on the toes.

Levers of the third order, (F. P. W.). Bending forearm; flexing the foot.

Standing, is accomplished by muscular action fixing the jointed body into one unbending column, and compensating for possible disturbance of equilibrium. The line of gravity of the whole body falls slightly in front of a line connecting the two ankle joints, so that the weight of the body would tend to flex the knee and ankle joints.

Standing is more fatiguing than walking.

Absolute stability in standing is impossible for any length of time; the body is continually swaying. This may be markedly exaggerated under pathological conditions, where the normal afferent impulses which pass to the co-ordinating centres which control the muscles involved in this act are wanting. (Locomotor ataxia.)

Walking calls into play almost every voluntary muscle, either directly for locomotion, or indirectly for balancing the head and trunk. The weight of the body is at first supported on one leg; a slight inclination forward throws the centre of gravity forward, and the other leg is raised and advanced to support the weight. The transfer of the weight of the body from one leg to the other causes it to oscillate slightly from side to side, carrying with it the centre of gravity. These oscillations are compensated for by the swing of the opposite arm. The forward inclination, interrupted by the support of the advanced leg, causes a slight up-and-down movement. (Peculiarities of gait.)

Speed in walking is attained by inclining the body more, and by flexing the legs more, so as to push the body forward with greater force.

Running is attained by inclining the body and flexing the legs still more, so as to make their extension-movement more effective in the forward propulsion. In running there are times when both feet are off the ground. Speed depends largely upon the vigorous action of the muscles, while in walking the amount of work performed is comparatively slight, since the swing of the leg is largely a passive act.

SECTION X.

THE NERVOUS SYSTEM.

The nervous system is formed of a mass of separate, but contiguous nerve-cells, found by dissection to be connected throughout its whole extent.

The parts usually distinguished—*central, peripheral and sympathetic*, —really merge into one another, and are only separated for convenience of consideration.

By virtue of its continuity (*vide infra*), the nervous system brings into connection all the other systems of the body.

All incoming impulses must reach the central system, whereby co-ordination and harmony in the outgoings are brought about.

The physiological connections existing between the nerve elements in youth are very incomplete and poorly established; growth here implies an increase in complexity, modified by the experience of the individual during the growing period.

CHAPTER I.—NERVE-CELLS. NEURONS.

Morphologically the nerve-cell is regarded as a cell-body containing a nucleus with one or more nucleoli and having one or more outgrowths, or branches.

It consists of a frame work continuous with the fibrillæ of the nerve-fibre and enclosing a substance within its meshes in small masses or granules.

The nerve cells vary in shape and size in different animals, and in different parts of the same animal. (The grey matter.)

The larger cells have wider connections, more material, and capacity for more energy.

From most cells arises one branch which, considered alone, is called a *nerve fibre*, but in connection with the cell-body from which it is an outgrowth, a *neuron or neuraxon*.

(Mononeuric, and dineuric cells.)

Collaterals are branches from the neuraxon, either near its origin, or along its course.

Dendrons or dendrites are outgrowths from the cell-body, much less extensive individually, which divide dichotomously, like a tree, hence their name.

The *nucleus* is small in proportion to the size of the nerve-cell but, in no other cell do we find so large a portion of the cell-substance occur as a branch. (In "granule-cells" nuclei large.)

The *neuraxons* may be less than a mm. in length, and as long as 100 cm. (from the central cortex to the lumbar enlargement of the spinal cord).

The *volume of the neuraxons and dendrons* is many times as great as that of the nerve cell: (220 to 1570 times in the neuraxons, and several times, in dendrons.)

The *neuroblast*, the origin of the nerve cell, is derived from the epiblast, and in early life before its branches have been formed is migratory, moving in an amœboid manner. Hence the perfection with which they arrange themselves in the adult system may be largely influenced by the conditions which attend their development.

Early in its history the point from which the neuraxon will grow appears to be fixed, and where cells are misplaced a confusion of arrangement results, as we find in the brains of some congenital idiots.

The branch which forms a neuraxon contains an *axis-cylinder*, surrounded or not by a *medullary sheath*; (sheath of Schwann; white substance of Schwann.)

(In the fœtus at first all nerve-fibres are non-medullated.)

The axis is composed of slender thread-like fibrillæ, floating in a coagulable plasma; these fibrillæ being the conductors of the nerve force.

(Others hold that the axis-cylinder is formed of a spongy framework, in the meshes of which is a semi-fluid plasma, which is the conductor of the nerve impulses.)

Not all neuraxons have a medullary sheath, nor is ever any neuraxon completely medullated. In the sympathetic system a large proportion is unmedullated; in the central system the number of unmedullated fibres is large, but the mass is small.

Of the signification of the medullary sheath nothing is positively known: probably nutritive. It is usually formed before the nerve-element, as a whole, has attained its full size. This, in the peripheral system, is usually completed during the first five years of life; the process continues in the central system, and especially in the cortex, to beyond the 30th year.

Nodes of Ranvier, produced by annular constrictions of the nucleated sheath of Schwann, or neurilemma. Probably for purposes of nutrition, for there the conditions for nutrition from the surrounding plasma are most favorable.

In old age the cell-body, together with the nucleus and its subdivisions, becomes smaller, the dendrons atrophy, and the neuraxon, probably, also diminishes in mass. In some instances the entire cell is absorbed.

Nerve Terminations.

Nerve fibres terminate peripherally:

- in subdivisions which pass in between epithelial cells, (interepithelial arborizations);
- in motorial end plates in voluntary muscles; in the nuclei of unstriped muscles.
- in special end organs connected with the senses of sight, hearing, smell and taste.
- in various forms of tactile corpuscles: (Pacinian corpuscles, tactile corpuscles of Meissner, tactile corpuscles of Krause, the tactile menisques, and the corpuscles of Golgi.

(Sensory fibres may also terminate in plexuses.)

Transmission of Excitation by means of End-organs.

The latest researches on the anatomy of the spinal cord seem to show that the incoming fibres do not communicate directly with nerve-cells, but terminate in *branch-like endings in the immediate vicinity of cells*

A similar arrangement is found whenever nerve cells are excited to action by nerve-fibres.

Either the brush-like endings are special exciting mechanisms, or they are sufficiently close to the nerve-cells or their protoplasmic processes to allow them to stimulate them by contact. Probably the former, for although the end-brush can excite the cell, the cell cannot excite the brush.

The same can be said of the end-plates, by which nerve fibre excitation is transmitted to the muscle-fibres, for the nerve fibres seem to come in contact with, rather than to be continuous with the muscle substance. Though the nerve end-organ can excite the muscle, the muscle cannot excite the nerve.

Nerve-Impulse.

The neurons form the pathway along which nerve-impulse travels. It travels, in mammals at the rate of about 34 metres per second; (modified by temperature; electrical condition; fatigue; increase of stimulation; length of neuraxon; drugs; and "personal equation").

In the peripheral system, the impulse when once started within a fibre, is confined to that track, and does not diffuse to other fibres running parallel with it in the same bundle.

In the central system the passage of the nerve-impulse is accomplished by a series of relays, in which each cell-body is roused to discharge its own impulse as the consequence of an impulse received from some other cell.

Each dendron represents at least one pathway by which impulses reach the cell-body. If the dendrons are numerous the cell-body is subject to a more complicated series of stimuli than if the branches are few. The complexity is, therefore, constantly increasing up to maturity.

The impulses which reach the cell-body produce there changes, probably chemical. When these reach a given volume and intensity, they cause a nerve impulse, which leaves the cell-body by way of the neuraxon.

Nerve nutrition.

The passage of nerve-impulses is one of the chief factors in determining the nutrition of the cell.

Where it is not thus kept active it usually atrophies, and may degenerate: (*e. g.* in the nerves which supplied a limb that has been amputated).

Fatigue causes the nucleus to shrink and become crenated, and the nucleolus also to diminish in size. These changes can, up to a certain point, be effaced by rest.

Histological and chemical changes, due to activity, have been seen in the cell-bodies alone, not in the fibres.

The *cell is the nutritive centre* for the fibre. The nutritive centre for the fibres of the posterior root of a spinal nerve is the ganglion on that root; of the anterior root, in the spinal cord. No proof of the existence of specific trophic nerves. If the fibre be separated from its cell it degenerates, and ultimately the muscles which it supplies.

Degeneration usually takes place in the direction of the nerve-impulse.

Regeneration has thus far only been demonstrated to be possible in the peripheral system not in the central. In mammals there is no convincing record of the formation of new cell-elements in the mature animal; and a cell once damaged in its nuclear portion is not to be replaced. The fibres are regenerated by an outgrowth of new axis cylinders, as fine fibres, from the axis cylinders of the central stump of the divided nerves.

The growth changes occurring in the central system up to the thirtieth year are from the enlargement of nerve-cells there present as structural units from a very early age.

Electrical Conditions in Nerves. (*Cf.* Muscular System.)

Nerves, like muscles, have so-called "natural nerve currents," or "currents of rest," which undergo "negative variation" on the stimulation of the nerve.

The term *electrotonus* has been applied to the effects of constant battery currents on nerves (and muscles).

The condition of the nerve in the region of the anode is called *anelectrotonus* (diminished excitability); of the kathode, *katelectrotonus*, (increased excitability). (Pflüger.)

If the anode be placed nearer the muscle than the kathode, the current is said to be "*ascending*," for the current in order to return to the battery must pass *up* the nerve.

If the kathode is the nearer, the current is called "*descending*."

"*Making*" and "*breaking*" contractions, are those produced respectively by the closing or opening of the circuit.

An *ascending current* produces a diminution of the irritability of the nerve (anelectrotonus), and a *descending current* an increase in its irritability (katelectrotonus).

The point between the two poles, where the irritability is not affected is called the "*neutral point*."

The nerve stimulus seems to gain strength as it descends, and a weaker stimulus applied far from a muscle, will have the same effect as a stronger one applied to the nerve nearer the muscle.

Pflueger's Laws of Contraction.

Strength of current used.	Descending.		Ascending.	
	Make.	Break.	Make.	Break.
Very weak	Yes.	No.	No.	No.
Weak	Yes.	No.	Yes.	No.
Moderate	Yes.	Yes.	Yes.	Yes.
Strong	Yes.	No.	No.	Yes.

Reaction of Degeneration.

The excitability of the muscle is diminished or abolished for the Faradic current; but increased for the galvanic.

The closing anodic contraction is stronger than the closing kathodic—the opposite of the ordinary law.

The excitability of the nerves is diminished for both Faradic and galvanic.

If the reaction of the nerves be normal, while the muscles show the reaction of degeneration, we speak of a "*partial reaction of degeneration*"; a condition which is constantly present in progressive muscular atrophy.

Where the reaction of degeneration occurs, we have to deal with some affection of the nerve fibres, or of the nerve-cells.

Summary of the Activity of the Nervous System.

The peripheral termini of the sensory or afferent nerves are isolated, and there pass into the central system as many distinct impulses as there are nerves that have been stimulated. Once entered into the central system, and transmitted to the central cells, by the collaterals and terminals of the afferent fibre by chemical (?) changes set up at the tips of the contiguous terminals, such an impulse has open to it many paths among the central cells, and by these pathways it can reach any group of efferent cells.

Both the diffusion and response are subject to many modifications.

The effect of a stimulus upon a nerve depends upon the nature of its end-organ.

CHAPTER II.—REFLEX ACTION.

The simplest and most constant of the co-ordinated reactions of the nervous system are reflex.

The term reflex usually implies that the response is not accompanied by consciousness, but it is not always possible to draw a line between reflex and voluntary reactions.

The *essential mechanism* demanded is:

- an *afferent path*, leading to the cord;
- *cells in the cord* by which the incoming impulse shall be distributed;
- *efferent fibres*, to carry the outgoing impulses, (affecting motion, secretion, or nutrition).

(In short, an afferent and an efferent neuron.)

The impulses causing reflex actions can make their circuit in a very limited portion of the spinal cord.

The intensity, extent, and duration of the reaction are influenced by the strength of the stimulus, and by the condition of the nerve centre.

All reflex actions are essentially involuntary, but most of them admit of being modified, controlled, or prevented by a voluntary effort.

Those occurring quite independent of sensation are generally called *excito-motor;* those accompanied by sensation, but not with perception, *sensori-motor;* and those both with sensation and perception, *ideo-motor.*

(In man true reflex-responses are mainly given by unstriped muscles and by glands.)

In health they are mostly purposeful; in disease often irregular and purposeless.

Their duration is longer than when the motor nerve is directly stimulated.

Many reflexes (*e. g.* micturition), are not controlled in the young, but later: some (*e. g.* sucking, and the clinging power of the hands), are lost later in life.

Pflueger's Laws of Reflex Action.

I. Law of unilateral reflection. A slight irritation of the surface supplied by sensory nerves is reflected along the motor nerves of the same region.

II. Law of symmetrical reflection. A stronger irritation is reflected, not only on one side, but also along the corresponding motor nerves of the opposite side.

III. Law of intensity. In the above case, the contractions will be more violent on the side irritated, but not always in proportion to the strength of the stimulus.

IV. Law of radiation. If the afferent impulse increases, it is reflected along other motor nerves, till at length all the muscles of the body are thrown into action.

Classification of Reflex Actions. (Kuess.)

I. Those in which both afferent and efferent nerves are cerebro-spinal: deglutition; sneezing. Pathologically, tetanus; epilepsy.

II. The afferent is cerebro-spinal, the efferent sympathetic, most often vaso-motor: secretion of saliva, or gastric juice; blushing,

pallor; certain movements of the iris. Pathologically, so-called metastases, ophthalmia or coryza depending upon reflex hyperæmia, etc.

III. The afferent is sympathetic, the efferent cerebro-spinal.

Here the majority are pathological: convulsions from worms; hysteria; eclampsia; etc.

IV. Both afferent and efferent belong to the sympathetic system: *e.g.* the nervous mechanism concerned in the secretion of the intestinal juice; those which co-ordinate the various generative functions; and many pathological phenomena, dilatation of the pupils from intestinal irritation, etc.

Instances of Reflex action.

Contraction of the iris—Afferent—optic nerve;
Centre—corpora quadrigemina;
Efferent—fifth nerve.

First respiration after birth—Afferent—sensory of the skin;
Centre—in the medulla;
Efferent—phrenic and intercostal nerves.

Sneezing from draft of cold air—Afferent—nasal of fifth;
Centre—in the medulla;
Efferent—phrenic and intercostal nerves.

Secretion of saliva. Afferent—nerves of taste;
Centre—in the medulla;
Efferent—chorda tympani.

The *time* occupied in a refllex action is from 0.05 to 0.06 of a second. The stronger the stimulus the shorter the time.

Inhibition and Augmentation.

These probably depend upon the existence of two pathways by which impulses reach a given cell: if they tend to excite the same response, there is augmentation, or reinforcement; if different responses, there is inhibition.

The Nervous System as a physiological unit, consists of the following parts:

- large masses of nervous matter within the bony cranium and spinal column, the *central system* or *cerebro-spinal;*
- smaller masses in the thoracic and abdominal cavities, also in the neck and head, the *sympathetic ganglia;*
- cords of nerve fibres which connect the central system with the periphery and with the sympathetic ganglia, the *peripheral system.*

Peripheral organs are in connection with the beginnings and ends

of the nerves at the periphery. (Mode of termination, *vide* Muscular system.)

The dorsal root-fibres among the spinal and cranial nerves, together with their homologues in the retina and the olfactory region, are the only channels for the entrance of impulses into the central system.

Once there, the impulses cause other cells to discharge, and these again others, through an indefinite series, until some of the impulses reach cell-bodies which give rise to efferent fibres, and which discharge away from the central system.

The efferent fibres pass out mainly by the *ventral* (*anterior*) roots, but in part by the lateral (when present), or by the dorsal roots.

The efferent fibres end either directly in striated muscle (*vide* Muscular system), or in the neighborhood of ganglia (sympathetic). The fibres from the ganglia in turn, very often connect with a peripheral plexus, about glands or blood-vessels; (motor, vaso-motor, secretory action).

We have therefore:

afferent or *centripetal* neurons, whose function it is to convey impulses, due to external stimuli, from the periphery to the central system;

central neurons, whose outgrowths never leave the central system; the function of which is to distribute within this system the impulses which have been received;

efferent neurons or centrifugal, whose neuraxons pass outside of the central system, and which convey impulses to the periphery.

These latter include:

(a) those whose cells lie within the central system; as those which give rise to the ventral roots;

(b) those entirely outside of the central system, the peripheral ganglia, the sympathetic ganglia, and the more or less solitary cells in the peripheral plexuses.

The central system is far more massive than the afferent and efferent taken together.

Organization. During fœtal life all the cells are isolated. By an increase in the number of dendrites, and of the relations in which these dendrites and terminal and collateral branches stand to each other, the nervous system becomes organized as a whole.

The neurons always remain only contiguous, and never become continuous.

Classification of Peripheral Nerves. (After Stewart.)

- Centripetal or afferent fibres.
  - 1. Nerves of special sensation.
    - Smell,
    - Taste,
    - Hearing,
    - Sight.
  - 2. Nerves of general sensation.
    - Tactile sensation,
    - Muscular sense,
    - Temperature,
    - Pain.
  - 3. Other nerves concerned in reflex changes in
    - Calibre of small arteries, (pressor, depressor),
    - Action of heart,
    - Visceral movements,
    - Respiratory movements,
    - Glandular secretion.
- Centrifugal or efferent fibres.
  - 1. Motor nerves for
    - Skeletal muscles.
    - Visceral muscles.
    - Vascular muscles.
      - Vaso-constrictor.
      - Cardio-augmentor.
    - Erector muscles of hairs (pilo-motor fibres).
  - 2. Inhibitory nerves for
    - Visceral muscles.
    - Vascular muscles.
      - Vaso-dilator.
      - Cardio-inhibitory.
  - 3. Secretory nerves.

CHAPTER III.—THE CEREBRO-SPINAL SYSTEM.

The whole cerebro-spinal axis is wrapped in four concentric sheaths:

The *dura mater* next to the walls of the bony cavity in which it lies.

The *pia mater* next to the nervous substance itself, following the convolutions of the brain and the fissures of the cord, and giving off blood-vessels supported in connective tissue septa to both.

The double layer of the *arachnoid*, between the dura and the pia, separated by a jacket of cerebro-spinal fluid from the latter.

From the pia mater coarse processes of non-nervous material run into the nervous substance, and the interstices are filled in by a thick-set network of interlacing filaments, given off by the small-bodied cells of the *neuroglia*. (From some cells the filaments are especially long, hence called "spider cells" or cells of Deiters.)

(The term *neuroglia* is applied by some to a granular mass, entirely without cells, filling in the spaces of the grey matter not occupied by other elements. But granular appearance may be due to cross section of fine connective tissue fibrils, or of the nervous plexus.)

PART I.—THE SPINAL CORD AND ITS NERVES.

The spinal cord is a cylindriform column of nerve-substance, connected above with the brain, through the medulla oblongata or bulb, and terminating below, at the lower border of the first lumbar vertebra, in the *filum terminale*, lying in the midst of the roots of many nerves forming the *cauda equina*.

It consists externally of white, and internally of grey matter, with a minute canal, the *central canal*, running through it, and opening above into the fourth ventricle of the brain.

The grey mattter, on transverse section of the cord, appears as two crescentric masses, connected by a narrower portion or isthmus, through which runs the central canal.

It consists of two symmetrical halves, separated anteriorly and posteriorly, by verticle *fissures* (the anterior the wider and more distinct), and united in the middle by nervous matter, the *anterior* and *posterior commissures*, composed mainly of collaterals.

Each half of the cord is marked off, on the side, by two longitudinal furrows, which divide it into three portions, *columns* or *tracts*, (anterior, lateral, and posterior).

From the groove between the anterior and lateral columns spring the ventral, or *anterior roots* of the spinal nerves.

Just in front of the groove between the lateral and posterior columns arise the *posterior* or dorsal roots of the same: a pair of roots on each side corresponding to each vertebra. (31 pairs of spinal nerves.)

Each part of the cord is proportionate to the number and size of the roots given off from it; (cervical and lumbar enlargements). At least half the nerve fibres entering the cord must terminate in it.

The *white matter* is made up of medullated nerve fibres (processes of nerve-cells; *vide supra*.), and a supporting material of two kinds,

ordinary connective tissue (from the mesoblast) and neuroglia, (from the epiblast).

The *grey matter* consists of groups of nerve-cells: (i) in the anterior cornua; (ii) in the posterior cornua; and (iii) as instrinsic cells distributed throughout, and commissural in function.

Columns and Tracts of the white matter.

Besides the main divisions, (anterior, lateral, and posterior), the posterior is further divided, by a septum of the pia mater, into the *postero-external* (of Burdach), and the *postero-median* (of Goll).

Further, by means of the embryological method, and by the Wallerian degeneration-method, the following additional tracts have been traced:

of descending degeneration:

crossed pyramidal tract,
direct or uncrossed pyramidal tract,
antero-lateral descending tract,
a comma tract.

of ascending degeneration:

postero-median column, (of Goll),
direct cerebellar tract,
antero-lateral ascending tract, (of Gowers and Tooth),
postero-marginal zone (tract of Lissauer).

The commissural fibres do not degenerate either way, when the cord is cut, and are found in the *antero-lateral* columns, the *lateral limiting* layer, and the columns of Burdach, (*postero-external*).

Spinal nerves.

Each spinal nerve is a mixed nerve beyond the ganglion (found on the posterior root), giving off anterior and posterior, or ventral and dorsal, branches, as well as a visceral branch, *ramus communicans*, to the sympathetic.

The *anterior spinal nerves* are chiefly efferent in function, containing motor, vaso-motor, secretory, and heat (?) fibres.

The *posterior root-fibres* are afferent in function, almost exclusively; (some few efferent fibres found).

The ganglia on the posterior roots are probably centres of nutrition for the nerve-fibres given off from them.

Course of the Fibres of the Spinal-Roots.

1. The *anterior roots* enter the cord in three bundles, an internal, middle and external, all more or less connected with the groups of multipolar cells in the anterior cornu.

The *internal fibres* connect with internal group of nerve-cells of the anterior cornu of same side ;—or send collaterals through the comminissure to the anterior cornu of the opposite side.

The *middle fibres* are partly in connection with the lateral group of cells in the anterior cornu, and part pass backward to the posterior cornu.

The *external fibres* are partly in connection with the lateral group of cells in the anterior cornu, but some fibres proceed directly into the lateral columns without connection with cells, and pass upward in it.

Some fibres have no connection with the anterior cornu-cells, but connect directly with groups of intrinsic cells in the median and posterior portion of the grey matter of the cord.

2. The *posterior roots* enter the cord to the inner side of the posterior cornu, in two sets, an internal or median, and an external or lateral. The fibres as they enter the cord divide, one branch passing down a short distance, the other passing up a shorter or longer distance, sometimes nearly the whole length of the cord, generally only for one or two segments. These branches give off numerous collaterals.

The *lateral* set enters the cord opposite the tip of the posterior cornu, and in part pass to the marginal column of Lissauer, ascending or descending ; in part penetrate the posterior horn and come in relation with its cells.

The *median* set sends some fibres to Clark's column of cells, others to the median cells of the other side through the posterior commissure, and still others through the median grey matter to the anterior cornu-cells of the same side.

Besides these wide connections of the posterior root-fibres they are connected by numerous collaterals with the intrinsic cells of the grey matter at different levels of the cord.

Hence pathways are formed by which the incoming impulse may produce an effect at parts of the system remote from the point of entrance, as well as pass almost directly to the efferent cells in the neighborhood where they enter. Further, the impulse reaches a far greater number of cells than evidently discharge, and the pathway followed by the impulses which do produce the discharge is by no means the only pathway over which the impulses can and do travel.

(These deductions apply also to the encephalon and to the diffusion of impulses there.)

General course of motor fibres from above:

On leaving the cortical centres they converge to the

internal capsule (the anterior ⅔ of the posterior segment);—to the

crura cerebri, (along the crusta);—to the *pons*;—to the

medulla, (anterior pyramids,); at the lower part they decussate; 95 p. c., crossing to the

lateral or *crossed pyramidal tracts* of the cord; while 5 p. c. pass down on their own side as the

anterior, or *direct pyramidal tracts.*

Course of sensory fibres:

Some decussate immediately on entering the cord, others not until they reach the medulla.

A lesion in one lateral half of the spinal cord in man is followed by a loss or impairment of motion on the same side, and a loss of sensation which is greatest on the side opposite the lesion.

Recurrent Sensibility.

If, after the division of the anterior root of a spinal nerve, the peripheral portion of it be stimulated, besides causing movements, there is evidence of pain being felt. This is due to the fact that some of the fibres of the sensory root bend up for some distance into the anterior motor root, and then turn again, and go as parts of the mixed nerve to the periphery, or run on in the motor root to supply the sheath surrounding it (nervi nervorum) and even the membranes of the cord.

Functions of the Spinal Cord.

I. Conduction.

Of Sensory Impressions, (touch, pain, heat, cold, muscle-sense, etc., from the periphery, by different routes, varying according to the character of the sensation to be conveyed.

Decussation takes place either in the cord, or in the medulla.

Of Motor Impressions downward from the brain, along the pyramidal tracts, viz., direct or anterior and crossed or lateral, (generally down the opposite side, having undergone decussation in the medulla or lower, in the anterior commissure), as well as over the few efferent fibres found in the posterior root.

Destination (1) voluntary, striped muscle-fibres: (2) sympathetic nerve-cells, (ganglia).

(Motor fibres for the legs partially pass downward in the lateral columns of the same side. This is probably generally the case with bi-lateral muscles, *i. e.* those acting together.

II. Reflection. (The functions attributed to so-called reflex nerves are now explained by the collaterals of the afferent fibres.)

In the spinal cord two kinds of reflex action are usually distinguished, which are of value in diagnosing nervous and other disorders:

(i) *cutaneous, or superficial:* plantar; gluteal; cremasteric; abdominal; epigastric; scapular. These are generally present in health, but are increased or exaggerated when the grey matter of the cord is abnormally excited; *e. g.* in tetanus, in strychnia poisoning, and in diseases of the lateral columns leading to arrest of their normal function.

(ii) *tendon or deep:* patellar; ankle clonos; ankle jerk. (These are marked in lateral sclerosis.)

Special (bilateral) Reflex Centres in the cord.

(a) *Defæcation or ano-spinal centre,* in the lumbar enlargement; partially under control of the will.

(b) *Micturition, or vesico-spinal centre,* also in the lumbar enlargement: may be excited to action (or inhibited) from the brain, or by the sensation of distension of the bladder.

(c) *Emission of semen, or genito-spinal centre,* also in the lumbar enlargement; not under voluntary control.

(d) *Erection of the penis centre;* same location. Its stimulation produces dilatation of the vessels of the penis; partly by reflex contraction of the muscles which, by their contraction, prevent the blood from returning from the penis.

(e) *Parturition centre;* situated rather higher up in the cord than the preceding. Independent of the will. (Delivery of women paraplegic, or under chloroform.)

The following are classed by some as *automatic centres; i. e.* such as do not require an afferent impulse to bring them to action:

(f) *Centre for muscle-tonus,* or passive contraction.

(g) *Vaso-motor* and *sweat centres.*

(h) *Trophic centres* for the muscles, bones, joints and skin, all of which suffer when the spinal cord is affected. (Existence doubtful.)

(i) *Heat-regulating centres.*

So-called *acquired reflex actions* are the result of repetition and education; in them the will exercises only an originating and controlling influence.

PART II.—PROLONGATIONS OF THE SPINAL CORD INTO THE BRAIN.

Cord.	Medulla.	Upward Prolongation.
Direct pyramidal tract, (columns of Türk).	Anterior pyramids of same side; do not decussate.	Upward through pons and crura cerebri.
Lateral column of cord.	Anterior pyramids of opposite side: (outer portion decussate.)	
Lateral column, (exclusive of the above).	Lateral tract.	I. External bundle joins restiform body, and passes to cerebellum.
		II. Middle bundle, beneath olivary body, behind pons, to the cerebrum, as the fasciculus teres.
	Olivary body; (White and grey matter); corpus dentatum.	III. Internal bundle decussates at the middle line, and joins the opposite anterior pyramid, (*vide* anterior pyramid, supra).
Posterior columns and lateral (direct cerebellar tract.)	Restiform bodies,	Lateral boundaries of 4th ventricle, and the inferior peduncles of the cerebellum, (perhaps some fibres into the cerebrum.)
Posterior median columns (columns of Goll.)	Posterior pyramids.	In connection with the fasiculus teres to the cerebrum.
Burdach's columns.	Funiculus cuneatus,	Both join in the grey matter of the medulla.

Medulla Oblongata or Bulb.

This is a prolongation of the spinal cord, consisting of grey and white matter; divided, by the anterior and posterior fissures, into two lateral halves. Each half divided by deeper grooves into four columns, viz.:

anterior pyramids;
lateral tracts (and olivary bodies);
restiform bodies;
posterior pyramids.

It extends from the foramen magnum below, to the lower border of the Pons Varolii above.

At the posterior part of the anterior fissure we find the *anterior decussation.*

Further up at the reticular formation a *second* (*sensory*) *decussation.*

The *posterior fissure* widens out to form the *4th ventricle*, into which the central canal opens and which has for its lateral boundaries the restiform bodies.

It consists of grey substance, besides that which is irregularly continuous with that of the cord.

It contains various *nuclei of grey matter*, particularly in the posterior part, connected with the roots of origin of several cranial nerves, viz.

hypoglossal,
spinal accessory,
vagus,
glosso-pharyngeal,
a root of the auditory,
a root of the facial,
a root of the trigeminus.

Functions of the Medulla.

It acts as a *conductor* of *sensory impressions* to the cerebrum, through its grey matter;
of *voluntary impulses* from the brain, through its anterior pyramids;
of *co-ordinating impulses* from the cerebellum, through the restiform bodies.

It contains also *centres*

of respiration, acting reflexly (or automatically);
vaso-motor centres;
cardiac accelerator centres, through the sympathetic;
inhibitory, through fibres of the spinal accessory in the vagus.

Ocular (superior cilio-spinal), closing the eyelids, and affecting movements of the iris.

Auditory, (inner and outer nuclei).

Centres for

mastication, sucking, deglutition ;
secretion of saliva ;
co-ordinating speech ;
expression, through the facial ;
vomiting ;
sweat ;
spasm ;
diabetic ;
inhibitory heat centre (hypothetical).

All on the floor of the 4th ventricle.

Pons Varolii.

This unites the cerebrum above, the two halves of the cerebellum behind, and the medulla below.

It transmits motor impulses and sensory impressions from and to the cerebrum, and from one part of the spinal axis to another.

Of its function as a nerve centre but little is certainly known, but it is supposed that its grey matter is the seat of *instinctive reflex acts*, also the centres which assist in the co-ordinating of the *automatic movements of standing* and *locomotion*.

We also find in the grey matter of the upper part of the 4th ventricle *nucleï* of the

facial, motor of the 5th, sensory of the 5th, auditory, and 6th (abducens) nerves.

Crura Cerebri.

Consist of two thick strands of nerve-substance connecting the pons with the cerebral hemispheres: diverging slightly in their upward course.

The *lower* and more *anterior* but more superficial part consists of longitudinal layers, the *crusta*, or *pes*, constituting the motor tract, and terminating for the most part in the corpus striatum, and, in part, in the cerebrum : continuous with the anterior pyramidal tracts of the medulla.

The *posterior* or *upper*, and therefore the deeper part, is the sensory tract, the *tegmentum*, terminating in the optic thalami and cerebrum : continuous with the lateral and posterior pyramids of the medulla.

Separating these two portions is a central nucleus containing pigment, the *locus* or *nucleus niger*, or *substantia nigra*.

The crura transmit both motor impulses and sensory impressions.

The locus niger assists in the co-ordination of the complicated movements of the eyeball and iris, through the motor oculi communis nerve.

Injury to the crura results in rotary or disorderly movements with loss of co-ordination.

Corpora quadrigemina or Optic lobes.

Two on each side, anterior and posterior.

Consist of grey matter within, and white externally.

Connected with the optic thalami.

The *anterior*, the *nates*, and *lateral geniculate bodies* are connected by fibres with the optic tracts.

They translate the terminal impressions into visual sensations (?); preside over the reflex movements which cause dilatation and contraction of the iris; assist in co-ordinating the movements of the eyeball, and regulate the movements of the iris during accommodation for distant vision.

The *posterior*, the *testes*, and *internal geniculate bodies* are connected with the cochlear division of the auditory nerve, and therefore have some relation to the sense of hearing. (Stimulation causes peculiar cry and dilatation of pupil.)

Removal of both optic lobes produces total loss of vision: of one, produces blindness in the eye of the opposite side; also rotary movements, slower than those caused by division of the crura.

They seem to correlate retinal impressions and oculo-motor reactions.

Their action is crossed, owing to the decussation of the optic tracts.

Corpora striata.

Two large ovoid collections of grey matter, at the base of the cerebrum; the larger portion of which is embedded in white matter; the smaller portion projects into the anterior part of the lateral ventricle and forms the *caudate nucleus*.

The extra-ventricular part is the *lenticular nucleus*, on the outside of which is the *external capsule*.

Their function is not definitely determined, but they may be

considered motor in part, and the motor connection between the cerebrum and the crura.

Injury causes hemiplegia on the opposite side.

(Experimental lesions of the caudate or lenticular nucleus followed by disturbances of the heat-regulating mechanism and rise of temperature.)

Optic thalami.

Are two oblong or oval masses, posterior to the corpora striata, resting upon the posterior portion of the crura.

The *internal capsule* is a narrow tract of white matter, for the most part an expansion of the motor tracts of the crura, separating its caudate nucleus, and the optic thalami from the lenticular nucleus, and dispersing in the *corona radiata* to the cerebral cortex.

Function of the optic thalami not determined. Injury, never positively isolated, causes loss of sensation on the opposite side ; may therefore be considered as the sensory connection between the cerebrum and the crura. The posterior portion of the thalamus, or *pulvinar*, seems to form part of the central visual apparatus. A lesion of the pulvinar may give rise to hemianopia.

PART III.—CEREBELLUM.

This consists of two lateral hemispheres, and a median elongated lobe, the *vermiform process.*

The two hemispheres are conected by fibres of the *middle peduncle* forming the superficial portion of the pons.

It is connected with the cerebrum by the *superior peduncles*, and, with the medulla and cord by the *inferior peduncles*, composed of prolongations of the restiform bodies.

The *internal white matter* consists of a stem, near the interior of which is a dentated capsule of grey matter, the *corpus dentatum* linked through the superior peduncle with the red nucleus of the tegmentum of the crus cerebri on the opposite side, and thus with the cortex of the opposite cerebral hemisphere.

The *external matter* which covers the laminæ of the spreading white matter, convoluted. In it we find,

delicate connective tissue,
cells of Purkinje,
a granular layer.
a nerve fibre layer.

Its *function* is the co-ordination of movements concerned in the maintenance of equilibrium, and its action is crossed. (A general co-ordinative power not demonstrated.)

No plausible grounds for considering it the seat of the sexual function.

The middle lobe is associated with the vagus, hence we so often have vomiting with vertigo in cerebellar diseases.

PART IV.—CEREBRUM.

Constitutes the largest part of the encephalic mass.

Average *weight* in adult male 48 to 50 oz.; in female about 5 oz. less. In idiots 20 oz.

The most cultivated races have the greatest capacity, but mental powers depend also upon texture, and number, and depth of convolutions.

After fifty years the weight begins to lessen.

It is very *vascular* ; $\frac{1}{5}$ of the entire volume of blood being distributed to it by the carotid and vertebral arteries.

This great vascularity is necessary to the carrying out of its functions, hence also the free anastomoses between the large arteries.

The grey matter much more vascular, (with anastomosing cortical arteries) than the white, (with its end-non-anastomosing arteries). (*Vide* blood supply, *infra* p. 140.)

It is connected with the medulla by the crura cerebri, and with the cerebellum by the superior peduncle.

A longitudinal fissure divides it into two ovoid masses, the *hemispheres*.

The *cortex* or *convolutions* are of grey matter, with as many as five layers of cells.

The *white matter* is arranged in

- longitudinal fibres, as the *fornix*,
- transverse, as the *corpus callosum*. peduncular fibres, connecting the grey matter on the surface with the corpora striata (*corona radiata*), and the latter with the pons (crura).

Fissures are numerous ; the principal ones are :

- of Sylvius,
- of Rolando, (location of most motor areas),
- parietal,
- parieto-occipital.

Function of the Cortex, or Convolutions.

It is the organ of the judgment and the will, and the medium of all higher emotions and feelings.

It is not homogeneous in function: the frontal lobes seem to be concerned with the *intellectual function;* the posterior with *sensations* and *perceptions;* while in the middle, various *motor areas* have been defined.

Cerebral localization.

Our knowledge of the localization of function has been derived from clinical, combined with pathological, observations on man, and from experiments on animals.

The *motor areas* lie around the the fissure of Rolando, lapping over on the mesial surface of the hemispheres in this region. They occupy the whole of the ascending frontal and parietal convolutions, running forward a little into the horizontal frontal convolutions, backward a little into the superior parietal convolution, and turning over on the mesial surface into the marginal convolution.

They comprise *centres* for the

- leg, including smaller foci for the hip, knee, ankle joints and the great toe;
- arm;
- face, mouth, pharynx, and larynx;
- head, neck, and eyes.

Stimulation of any one of these areas leads to contraction of muscular groups which have to do with the execution of definite movements; essentially so-called skilled movements; (*e. g.* stimulation of the upper extremity of the ascending parietal, and ascending frontal convolutions causes movement of the leg; stimulation of these areas lower down, causes movements of the arm).

The centres which govern the more massive parts, and the lower regions of the body, are high up in the brain, while the centres for control of the face and arm, for example, are lower down on the surface of the cortex.

Sensory Areas.

Visual centres, in the occipital lobes, destruction of which causes hemianopia, *i. e.* loss of vision in corresponding halves of the retinae.

Auditory centres, on the outer surface of the tempero-sphenoidal lobe, in the 1st and 2d temporal convolutions.

The *centre of smell* is undetermined, but possibly lies in the uncinate gyrus, on the mesial aspect of the temporal lobe.

The *speech centre* is located in the 3d frontal convolution and the island of Reil, on the left side in right-handed persons.

Amnesic-aphasia, or *sensory aphasia* is the inability to comprehend the meaning of spoken or written language, although sensations of hearing and sight are not abolished.

Motor aphasia is the inability to clothe ideas in words, although the ideas conveyed by speech or writing may be perfectly comprehended. Motor aphasia is commonly due to a lesion in the left hemisphere alone, because that side is better developed in right-handed persons in the motor areas, which are in close proximity to the speech centre.

(*Temporary aphasia* may occur without any structural change in the speech centre, *e. g.* in migraine, and in children, due to tape-worm.)

In sensory aphasia two regions have been found affected, the occipital and the temporal cortex.

When the lesion is confined to the occipital region spoken language is perfectly understood, written not at all.

When the lesion is confined to the temporal region, it is the spoken word that is missed, and the written that is understood.

It may exist in any degree of completeness up to total word-deafness, or word-blindness.

Sometimes both sensory and motor aphasia may exist together.

(*Cortical* or *Jacksonian epilepsy* is associated with lesions in the Rolandic area, and it has been found possible to locate the exact seat of the lesion from the part of the body in which the "aura" begins.)

Sleep.

Sleep is necessary to recover from the sensation and result of fatigue. (Certain gland-cells, muscular fibres, and the epithelial cells of ciliated membranes never rest. Local exercise is capable of producing general fatigue.)

The active tissues (nerve-cells and muscles) yield, as the result of their activity, by-products, which are carried through the blood to the central system, and become one of the chief causes of sleep.

(The blood of exhausted dogs, when transfused into a fresh animal, has caused all the symptoms of fatigue.)

Cessation of stimuli, decreased responsiveness of the active tissues, change in the composition of the blood, and diminution of the blood-supply to the brain, are the preliminaries to sleep.

In normal sleep the changes taking place in the central system are recuperative.

A condition resembling sleep can be induced by removing external stimuli; by extreme cold; by a blow on the head; by hypnotic suggestion; by compression of the carotids; by loss of blood.

During sleep the nervous system is capable of reactions which are not remembered. (Dreams. Somnambulism.)

The depth of sleep as determined by the strength of the stimulus necessary to elicit a response has been measured. It appears that the period of deep sleep is short, less than two hours, and is followed by a long period, that of an average night's rest, during which a comparatively slight stimulus is sufficient to awaken. Hence continuous sleep is necessary to accomplish repair. The amount necessary varies with age, occupation, perhaps climate and idiosyncrasy.

Loss of sleep has been found more damaging to young dogs than starvation, causing fatty degeneration of the tissues, capillary hæmorrhage in the cerebral hemispheres, dry and anæmic condition of the spinal cord.)

Hypnotism is in some respects allied to natural sleep, but instead of the whole activity of the brain being in abeyance, the susceptibility to external impressions is as great, if not greater, than in the waking moments, while the critical faculty of judgment is asleep. (Methods. Phenomena.)

Simultaneous action of the hemispheres.

One hemisphere seems to be able to act alone, even after considerable injury to the other.

The two hemispheres must act simultaneously or there will result two mental impressions.

PART V.—THE CRANIAL NERVES.

The **NUCLEI** of origin of the cranial nerves, with the exception of the olfactory and optic, are crowded together in the inch or two of grey matter of the primitive neural axis in the immediate neighborhood of the 4th ventricle and aqueduct of Sylvius.

The sensory nuclei, are those of the 5th and 8th, and probably the common nucleus of 9th, 10th and 11th.

The motor nuclei lie, upon the whole, in two longitudinal rows,—a *median* row, which contains the nuclei of the 3rd and 4th, in the floor of the aqueduct; and the 6th and 12th, in the floor of the 4th ventricle; and a *lateral* row comprising the motor nuclei of the 5th, 10th and 11th, and the nucleus of the 7th.

1st Cranial nerve, or **olfactory,** is really a lobe of the brain, better called the *olfactory tract*, the real olfactory nerves being the short terminal twigs which pierce the cribriform plate of the ethmoid bone.

(The olfactory tract can be traced to the uncinate gyrus of the same side, but it seems to be related in some way to the opposite side of the brain, for an injury to the posterior part of the internal capsule has been associated with impairment of hearing.)

2d, or optic, is connected centrally with the posterior portion of the optic thalami, (the pulvinar), the anterior corpora quadrigemina, and, both directly and indirectly, with the occipital cortex.

Peripherally it expands into the retina.

The fibres of the nasal halves of both retinæ decussate at the chiasm. Those of the temporal halves do not.

3d, or motor oculi communis, arises from a series of nuclei in the floor of the aqueduct of Sylvius, below the anterior corpora quadrigemina.

The *most anterior nuclei* send off fibres having to do with the mechanism of accommodation.

The *nuclei behind these*, send off fibres which cause contraction of the pupil, when light falls upon the retina.

The *posterior nuclei*, give off fibres to all external muscles of the eyeball, (except the superior oblique, and external rectus), also to the levator palpebræ superioris.

Complete paralysis of the 3d nerve causes loss of the power of accommodation, dilatation of the pupil, diminution of the power to move the ball, ptosis, external strabismus, and consequent diplopia.

It is purely motor in function.

4th, or patheticus, or trochlear, arises from the posterior part of the same tract of grey matter which gives origin to the 3d nerve.

It supplies the superior oblique muscle of the eyeball.

Paralysis causes internal and upward strabismus, with diplopia on looking down.

Unlike the other cranial nerves these decussate after they emerge from their nuclei of origin.

Function purely motor.

5th, or trigeminus, or trifacial. Its deep origin is more extensive than that of any of the other cranial nerves, stretching as it does from the level of the anterior corpora quadrigemina above, to the upper part of the cord below.

The *motor root* arises from a nucleus in the floor of the 4th ventricle.

The *sensory root* has two deep origins: one, a nucleus in the floor of the 4th ventricle, the other a long ascending root from the level of the second cervical nerve, through the medulla and the tegmentum of the pons.

The *motor fibres* supply the muscles of mastication and the tensor tympani.

The *sensory* supply common sensibility to the face, the conjunctiva, the mucous membrane of the mouth and nose; and special sensation, through branches given off to the facial and glosso-pharyngeal nerves, to organs of taste.

Complete paralysis causes loss of movement of the muscles of mastication, sometimes impaired hearing, and loss of common sensibility in parts supplied by it.

Loss or impairment of taste in the corresponding half of the tongue is often seen in lesions involving the sensory fibres, after they have left their origin.

Vaso-motor changes are occasional, and trophic changes frequent.

It has four ganglia: ophthalmic or lachrymal; spheno-palatine; otic; and submaxillary. (*Vide* Ganglia of the Sympathetic.)

It is a nerve of motion, sensation, and taste.

6th, or abducens, takes its origin from a nucleus in the floor of the 4th ventricle, at a level with the posterior portion of the pons. It is the motor nerve for the external rectus muscle of the eyeball.

Paralysis causes internal strabismus.

7th, or facial,—portio dura,—arises from a nucleus in the reticular formation of the medulla, and running up some distance into the pons.

Supplies the muscles of the face, and is the nerve of expression.

It is motor in its origin but receives sensory filaments from the 5th and 10th nerves.

It gives off the *chorda tympani*, which supplies the blood-vessels and secreting cells of the sublingual and submaxillary glands (salivary secretion), and the sense of taste to the anterior $\frac{2}{3}$ of the tongue.

(Since the fibres which connect the nucleus with the cerebral cortex decussate about the middle of the pons, a lesion above this level, which causes hemiplegia, also paralyses the face on the same

side as the rest of the body, *i. e.* on the side opposite the lesion, but the paralysis is confined to the lower portion of the face, especially the muscles about the mouth.

If the pyramidal tract and the facial or its nucleus are involved in the lesion, then the face is paralysed on the side of the lesion and is total, together with the rest of the body on the opposite side.

Symptoms of complete paralysis of the facial are characteristic. Taste is lost in the anterior ⅔ of the tongue, when the lesion is between the fibres of the trigeminus and chorda tympani. Hearing is impaired, because the auditory and facial nerves are near together, and the 7th supplies also the stapedius muscle.

8th, or auditory or portio mollis, arises from the medulla by two roots, with nucleus in the floor of the 4th ventricle, and is distributed to the labyrinth of the ear.

It is believed that the dorsal root carries fibres distributed to the cochlea, and the ventral to the semicircular canals and vestibule.

Disease of the nerve is attended by loss or impairment of hearing, and loss or impairment of equilibrium.

9th, or glosso-pharyngeal, from the upper portion of an elongated nucleus in the medulla, (the middle portion of which gives origin to the vagus, and the lower to the accessory division of the spinal accessory). An additional origin ; the ascending root, from the grey matter of the lateral horn of the cord and the reticular formation of the medulla, commences as far as the 4th cervical nerve.

Has both *sensory fibres* for the posterior ⅓ of the tongue, and the mucous membrane of the back part of the mouth, and motor, for the middle constrictor of the pharynx, and the stylo-pharyngeus muscle, for the tonsils, soft palate and tympanum.

It also contains *nerves of taste* for the posterior ⅓ of the tongue, but these reach it from the 5th.

It governs the sensibility of the pharynx and influences the taste, besides its motor function.

10th, or pneumogastric, or vagus, is joined near its origin by the accessory portion of the spinal accessory, *i. e.* the portion which arises from the medulla.

The mixed nerve contains both sensory and motor fibres, the latter from the accessory, the former entirely from the vagus.

Its distribution is most extensive.

The *œsophagus* receives both sensory and motor fibres.

It is the chief motor nerve of the *pharynx* and *soft palate* (including tensor palati.)

Its *superior laryngeal branch* is the nerve of common sensibility for the larynx above the vocal cords, and the motor nerve for the crico-thyroid muscle: (stimulation causes coughing, slows respiration, or stops it in expiration).

Its *inferior laryngeal branch*, or *recurrent*, supplies the rest of the laryngeal muscles, and is sensory for the mucous membrane of the larynx below the vocal cords, and of the trachea.

The *lungs* receive both sensory and motor fibres through the pulmonary plexus. Stimulation of the motor fibres causes constriction of the bronchi: of the sensory fibres, causes increase in rate of respiration, or stoppage of the diaphragm in inspiratory spasm.

The *cardiac fibres* from the spinal accessory, are inhibitory, and depressor, passing up in the vagus trunk (dog) or as a separate nerve to join the vagus or its superior laryngeal branch or both (rabbit).

Gastric and *intestinal branches*, both sensory and motor.

The afferent fibres from the stomach carry up impulses which cause vomiting.

11th, or spinal accessory, consists of two parts, the accessory branch from the medulla, connecting as above, with the vagus, and the spinal branch from the lateral columns of the cord, which is distributed to the trapezius, and sterno-mastoid muscles with motor fibres.

12th, or hypoglossal, is the motor nerve of both the extrinsic and intrinsic muscles of the tongue, and for the thyro- and genio-hyoid muscles.

Influences mastication, deglutition, and articulate language.

Paralysis causes deficient movements of the corresponding half of the tongue. When the tongue is protruded it deviates towards the paralyzed side, pushed over by the unparalyzed genio-hyo-glossus of the opposite side.

CHAPTER IV.—THE SYMPATHETIC NERVOUS SYSTEM.

It is associated with the efferent neurons of the cerebro-spinal system alone, by the *rami communicantes:* Composed of nerve cells, grouped more or less into *ganglia*, which ganglia are interpolated between the efferent neurons of the spinal nerve-roots on the one hand, and the peripheral plexuses or secreting cells on the other.

(*Pre-ganglionic* fibres, *i. e.* fibres growing out of cell-bodies situated in the cord, arise from the first thoracic to the fourth or fifth lumbar, and from these alone.

The branches of the pre-ganglionic neurons are distributed to a number of ganglion cell-bodies, and these cells in turn send their neurons either to the peripheral structures controlled by the sympathetic element, or to the plexuses such as are found in the intestines and around blood-vessels.)

Distribution.

It consists of a double chain of ganglia and fibres on each side of the vertebral column from cranium to pelvis.

In the cranium the two cords are connected by the ganglion of Ribes, on the anterior communicating artery ; and below, by the ganglion impar, at the top of the coccyx.

Groups of Ganglia:

- cervical ; superior, middle, inferior (pupil dilating) ;
- thoracic ; splanchnic, greater and lesser ; and renal (vaso-motor ;
- semi-lunar ;
- solar, and epigastric, (cardio-inhibitory) ;
- lumbar ; aortic, and hypogastric ;
- pelvic ; sacral and coccygeal.

With these may be included :

- the small ganglia in connection with those branches of the 5th cranial nerve which are distributed in the neighborhood of organs of special sense, *viz.* : ophthalmic, otic, spheno-palatine, and submaxillary, (*vide* 5th nerve) ;
- various ganglia and plexuses in the substance of many of the viscera, as the stomach, intestines, and urinary bladder.
- By many are included also the ganglia on the posterior roots of the spinal nerves, on the glosso-pharyngeal and vagus nerves, and the Gasserian ganglion on the sensory root of the 5th cranial.

Functions of the Sympathetic System.

It sends fibres to the muscles of the *vascular system*,

- vaso-constrictor and cardio-accelerator ;
- vaso-dilator and cardio-inhibitory :

to the *visceral muscles*,

- viscero-motor,
- viscero-inhibitory .

to *secretory gland-cells*, (salivary, lachrymal, and sweat).

GENERAL CONSIDERATIONS ON THE ENCEPHALON.

Weight of the Encephalon.

According to weight, it may be classed as,

macrocephalic,
large,
medium,
small,
microcephalic.

In the majority of persons the brain-weight falls within the group of medium brains (weight in adult males 1450 to 1251 grams; in females, 1350 to 1150 grams.

Within the limits of a given race differences in brain-weight depend upon sex, age, stature, and body-weight. In all the difference is dependent upon the variations in the size rather than upon the number of their elements.

High brain-weight and unusual mental capabilities are by no means necessarily associated. (A mouse more brain-weight than man, in proportion to its size.)

Growth of the Brain.

At birth the brain is about ⅕ the weight it will attain at maturity.

The growth during the first year is very rapid; vigorous for the first 7 or 8 years; after which it becomes comparatively slow. The maximum is reached in the fifth decade (males), in the fourth in females, with a pre-maximum at 13th to 15th year in males and at 14 in females, at which ages the too vigorous growth of the encephalon appears to be an important factor in the cause of death.

Human embryology indicates that after the third month of fœtal life, the number of cells in the central system is not increased; subsequent growth does not result from the development of new cells and new fibres, but from development of elements present in the system from an early period in an undeveloped state.

With its growth the nervous system becomes capable of new reactions, in the sense that its various responses are controlled and directed by a larger number of incoming impulses, and thus the number, complexity, and refinement of the reactions are increased, and in this sense it really acquires new powers.

Defective development may result not only in an absence of

certain powers, but also in a diminution in the strength of those remaining.

Blood supply and circulation.

The arrangement of the blood-vessels is peculiar.

Four great arteries to the brain, two internal carotids and two vertebrals.

The vertebrals unite to form the basilar, which splits into the two posterior cerebrals. Each carotid divides into a middle and an anterior cerebral artery. A communicating branch unites the middle and posterior cerebrals on each side, and a short loop connects the two anterior cerebrals in front. In this way the *circle of Willis* is formed. While the anastomoses between the large arteries is thus free, the opposite is true of their branches. All the arteries in the substance of the brain (and cord) are "*end arteries*," *i. e.* terminating within the area of their distribution without communicating branches.

The consequences of this arrangement are that—

1. Interference with the blood-supply between the heart and circle of Willis does not produce symptoms of cerebral anæmia, *e. g.* both common carotids may be tied without harmful effects;

2. Blocking of any of the arteries which arise from the circle or any of their branches leads to destruction of the area supplied by it. (Stewart.)

In the adult the cranium is a closed rigid cavity, hence the quantity of blood in the central system is subject to but slight variations.

A rise of blood pressure causes a more rapid flow of blood through the encephalon.

The flow is subject to the laws of gravity.

The principal controlling mechanism is the splanchnic area. During the first phases of mental activity blood is withdrawn from the limbs, and if the skull wall is defective the brain is seen to swell.

In the later stages of fatigue the blood-supply to the nerve centres diminishes, owing to the decrease in force of the heart beat, and in the tonicity of the splanchnic vessels.

In the growth of the nervous system the thyroid gland seems to exert an important influence in giving to the blood a quality necessary to its proper nutritional function.

Old age of the nervous system.

In youth the anabolic changes overbalance the katabolic, in middle age there is an equilibrium; in old age, although the total

expenditure is diminished, the anabolic processes become incapable of repairing the waste. In the favorably situated, senile atrophy does not begin until after the sixtieth year.

The nervous system as a whole becomes less vigorous in its responses, less capable of repair, and of extra strain, and less permeable to the nervous impressions which fall upon it, so that its capabilities are lost in a fragmentary and uneven way.

There is a decrease in the thickness of the cerebral cortex, due to a shrinking in volume and number of fibre elements, principally of the motor areas.

In the cerebellum some cells have been found shrunken and some of Purkinje's cells have completely disappeared, in persons dying of old age.

SECTION XI.

THE SENSES.

Our only knowledge of the external world and of the various parts of our own bodies is furnished us through the nervous system. It is based upon sensation.

Necessary to sensation are:

(a) a peripheral organ for the reception of impressions;
(b) a nerve to conduct them to the nerve centres;
(c) certain nerve centres, capable, by specific energy, of receiving the impulses, and translating them into sensations, which are commonly referred to some point of the periphery;
(d) associated nerve centres, capable of perceiving sensations, forming ideas, and drawing conclusions.

Sensations may be classified as **Common or General Sensations and Special.**

CHAPTER I.—COMMON OR GENERAL SENSATIONS.

By these we are made conscious of certain conditions of various parts of our bodies, but not of the external world.

(Fatigue; discomfort; pain; faintness; satiety; hunger; thirst; also nausea; giddiness; shivering; titillation, etc.

The various irritations of mucous membranes giving rise to the desire to cough, defæcate, urinate, can also be classed here.)

It is difficult to locate the seat of such sensations.

Pain is caused by a stronger stimulus than normal to any sensory nerve: every kind of stimulus may excite pain.

In general the skin is far more sensitive to pain than the deeper structures, (the cutting of healthy muscle causes no pain), but spasmodic contraction of the intestines and stomach, and the normal contractions of the uterus in labor occasion severe pain.

Tissues normally insensible to pain may become acutely painful when inflamed.

Not definitely settled whether the afferent fibres which contribute to painful sensations are anatomically distinct from the fibres of

tactile sensation, and of the other sensations included under the sense of touch.

They seem to be so, for in certain cases of disease sensibility to pain may be lost, while tactile sensations are still perceived and vice versa. (According to Gowers the antero-lateral ascending tract of the cord is the pathway for sensibility to pain.)

The sensation is always referred to the periphery.

A violent stimulus in the course of a nerve may interfere with the power of conducting impressions (*anæsthesia dolorosa*).

Irradiation of pain by nervous connections.

Severity of pain depends upon the number of fibres affected.

Varieties of pain depend for the most part upon unknown causes, but also upon strength of stimulus and number of fibres simultaneously affected.

Individual peculiarities.

Anæsthetics:

local,

general.

CHAPTER II.—SPECIAL SENSES.

Touch; Taste; Smell; Hearing; Sight.

The *nerve fibres* which carry these impulses do not differ in structure from other nerves, but their normal stimuli are specific, the action of the nerve centres is specific, and the sensations are specific.

The *seat of sensation* is the sensorium in the brain.

It is capable of being excited by changes in its own condition; (subjective *vs.* objective sensations; illusions; hallucinations; delusions).

Perceptions, conceptions, and judgment are founded upon, but are to be carefully distinguished from sensations. They are the result of experience and education.

Evidence of our senses: in how far reliable.

TOUCH.

A modification of general sensibility, residing in the skin as the organ of touch. Few of the internal organs supplied with tactile nerves.

The modifications of this sense often depend upon the extent of the parts affected; (pricking *vs.* pressure).

This special sense can be regarded as including:

Tactile sensibility; acuteness; variations in different parts; æsthesiometer; Illusions.

Sense of pressure; distinct from touch proper, (only perceived when it affects two neighboring areas to a different degree); estimation of weight.

Sense of temperature; distinct from touch proper and pressure; hot and cold points (cold points more numerous); variations in different parts of the body (mucous membrane, very little sensitive); relative character of the sensation; time required for the conveyance of the impression to the brain; (pathway in the lateral columns of the cord (?)).

Pain, (*vide supra.*)

The nerves concerned are those derived from the posterior roots of the spinal cord, and the sensory nerve centres.

The modified epithelial cells which are the terminals of the nerves are:

tactile corpuscles; (in the papillæ of the true skin;

touch cells (in the deeper layers of the epidermis);

end bulbs of Krause, (in localized areas);

free nerve endings on the epithelial surface of mucous membranes; on the surface of the cornea;

Pacinian corpuscles.

Subjective sensations of touch frequent; *e. g.* neuralgic pains, rigor, formication, state of the sexual organs in sleep, etc.

TASTE.

Seat in the tongue, anterior surface of the soft palate, uvula and tonsils, and probably the upper part of the pharynx.

Anatomy of the tongue: *muscles*, extrinsic and intrinsic.

Papillæ: circumvallate, in posterior part, with taste goblets; "end organs" of the gustatory nerves;

fungiform, on sides and tip, in part gustatory;

filiform or conical; principally on dorsum in the anterior $\frac{2}{3}$; probably more tactile than gustatory.

Nerves:

glosso-pharyngeal to the posterior $\frac{1}{3}$,

lingual branch of the trifacial, and chorda tympani to the tip.

The motor nerve is the hypoglossal.

Also nerves of general sensibility.

Essential conditions for the sensation of taste, are :

solution or solubility of the substance,
moisture of the surface,
active movements of the tongue.

Varieties of taste: sweet and bitter; sour and salt; alkaline and metallic.

Different parts of the tongue are adapted to receive different sensations predominately, (sweet and acid tastes at tip, bitter at the base) although it seems probable that there are separate nerve fibres for each fundamental sensation, and that the majority of papillæ are provided with more than one variety.

The sense of taste is assisted by the sense of smell; (flavor "bouquet"; cold in head).

After tastes depend upon the endurance of sensation after the stimulus has been removed.

Delicacy of the sense of taste can be cultivated; blunted in born-criminals.

Subjective sensations are difficult to distinguish; may be due to alteration in composition of blood in disease, or to foreign substances introduced. (Illusions.)

SMELL.

Seat in the upper ⅓ of the nasal cavity, the *regio olfactoria*, where are distributed the filaments of the olfactory nerve; (cylindrical epithelium, prolonged cells; the lower part, the *regio respiratoria*, has stratified cylindrical ciliated epithelium).

(The olfactory nerve differs from other nerves in containing grey matter, and in being soft and pulpy in structure, its filaments resembling the sympathetic nerves, having no white substance of Schwan.)

Common sensibility (cold, heat, itching, tickling, etc.) is given to all parts of the nasal cavity by the nasal branches of the first and second divisions of the fifth nerve.

Conditions essential to the sense of smell, are :

minute division of the substance,
moist condition of the nasal membrane,
a current of air (sniffling) to bring the particles in contact with it. (Smelling of liquids?)

Varieties of odorous sensations.

(Idiosyncrasies; association of ideas; agreeable or disagreeable.)

Acuteness of sensation, in animals and in man.

Subjective sensations but little studied :

(Illusions ; in nervous persons ; in cerebral disease.

Electrical excitation of the olfactory mucous membrane causes a sensation like smell of phosphorus : at kathode on closure, at anode on opening.)

HEARING.

Anatomy of the Ear.

External ear:

auditory canal,

membrana tympani.

Middle ear:

ossicles (malleus, incus, stapes),

Eustachian tube,

mastoid cells,

fenestra ovalis, fenestra rotunda.

Internal ear:

osseous and membranous, (in it the end-organs of the auditory nerve);

vestibule (*utricle, saccule*) ;

semicircular canals ;

cochlea, (lamina spiralis, scala tympani, scala vestibuli, scala media ;

organ of Corti, (membrana reticularis) ;

filaments of the auditory nerve, (portio mollis of 7th).

Sound is *produced* by the stationary vibrations of elastic bodies.

Sound is *propagated* by progressive wave motion of elastic media, usually the air, (also water and solids).

Functions of the various parts of the auditory apparatus.

Function of the *external ear* is to collect sound, to conduct it to the membrana tympani, and to increase it by its own vibrations.

Function of the *tympanic membrane* is to receive the vibrations of the air and to transmit them to the ossicles.

Function of the *tensor tympani* and *laxator tympani* muscles, is through their action on the malleus to accommodate the membrane to vibrations of different intensities.

Function of the *bones* is to transmit the vibrations, by the vibration of their particles, as well as by their vibration *en masse*, across the tympanic cavity to the membrane covering the fenestra ovalis.

Function of the *stapedius muscle* is, by its contraction, to regulate the force of impact of the stapes against the membrane of the oval window.

Function of the *Eustachian tube* is to equalize the pressure within and without the drum cavity.

(Eustachian catheter; Politzer bag; Valsalva's method. Act of swallowing.)

Function of the *endolymph* is to receive the vibrations and to transmit them to the terminations of the auditory nerve which float in it. It communicates anteriorly with the cochlea and posteriorly with the semicircular canals.

To reach the cochlea the vibrations pass from the saccule, along the scala vestibuli to the top (helicotrema), into the scala tympani, returning through which they reach the fenestra rotunda.

They reach the semicircular canals from the utricle.

Function of the *cochlea* is to receive vibrations propagated by the solid parts of the head and the walls of the labyrinth.

Function of the *organ of Corti* is probably to discriminate between the quality of sounds.

Function of the *semi-circular canals* is to assist in maintaining the equilibrium of the body.

The nerves end here in peculiar epithelioid cells to which are attached fine hair-like processes, set in motion by the motion of the otoliths, which derive their motion from the vibrations of the endolymph.

The *limits of auditory perception* extend from between 16 to 23 vibrations per second and 40,960: may be pathologically increased.

Noise. Tone. Intensity. Pitch. Quality.

Perception of distance and direction acquired by experience.

Binaural sensations.

Subjective sensations arise from vascular congestion; exhausted or irritable nervous system; cerebral disease; disease of the auditory apparatus.

(Hallucinations: illusions: auto-hypnotism.)

Sensations of light and colors often associated with auditory sensations. Associated movements of other parts of body on reception of intense sensations.

SIGHT.

Anatomy of the Optical apparatus.

Eyelids, to protect, and to distribute moisture; with lashes, endowed with tactile sensibility so as to cause the lids to close (reflexly) to keep out foreign bodies; meibomian glands, to lubricate, and to prevent irritation from tears.

Lachrymal glands; tears; puncta lachrymalia; sac; duct.

Orbicularis muscle, to close the eye; controlled by the facial nerve.

Levator palpebrarum muscle to raise the upper lid; under the control of the oculi motor communis nerve.

Eyeballs:

conjunctiva, bulbi and tarsi, fornix;
sclerotic, with the cornea, (five layers);
choroid, with the ciliary processes and muscle;
iris with its pigment; contracted by third nerve, dilated by sympathetic(?).

Lens, suspensory ligament, (nucleus, cortex).

Retina (ten layers); fovea centralis; macula lutea; visual purple;
Aqueous and *vitreous humors.*

Optic nerve.

External muscles of the eyeball:

4 recti, externi and interni, superior and inferior;
2 oblique, superior and inferior.

Blood-vessels of the ball:

short and long posterior ciliary arteries and anterior ciliary. (Pericorneal injection.)
The retinal vessels are derived from the arteria centralis retinæ. (Embolism.)

Nerves of the ball:

the 3rd, or motor oculi, is supplied to all the muscles except the external rectus and the superior oblique,
the 4th to the superior oblique.
the 6th to the external rectus,

Nerves of the *cornea*, from the long and short ciliary, which are distributed as naked axis cylinders.

Nerves of the *iris*,

3rd to the circular, contracting fibres, facial and sympathetic to the radiating or dilating.

Nerve of the *retina*, the optic, whose filaments, supported by Müller's membrane, with its 10 layers, end in the *rods* and *cones*.

THE EYE AS AN OPTICAL INSTRUMENT:

The essential parts of the eye are:

(1) a nervous structure, retina, to receive and transmit to the brain the stimulation of the light;

(2) certain refracting media to concentrate and converge the various rays upon the retina, so that there may be a distinct image of each point, (dioptric media).

(3) a contractile diaphragm, iris, to regulate the amount of light admitted to the eye;

(4) an apparatus whereby the chief refracting medium the lens, may be accommodated to rays proceeding from objects at different distances, the ciliary muscle.

The *centre of direct vision* is the macula lutea, where we find only cones.

The *blind spot* corresponds to the entrance of the optic nerve, the *optic disc*, where no impression is produced by light.

(Purkinje's figures.) (Ophthalmoscope.)

Chromatic aberration, which is the breaking up of white light into its various component colors, and *spherical aberration* which is owing to the different refraction of rays which pass through the margin and through the centre of the lens, are both corrected by the iris, which cuts off all but the central rays.

The size of the pupil is affected by the intensity of the light striking the eye. In the dark it is dilated; when light falls upon the retina it becomes contracted, by a reflex mechanism of which the optic nerve forms the afferent, and the oculo-motor the efferent path, with the centre in the medulla, in the floor of the aqueduct of Sylvius.

Refraction is the optical adjustment of the eye depending upon its anatomical structure.

An *emmetropic*, or normal eye, is one in which parallel rays are exactly focused upon the retina.

Errors of Refraction:

Myopia, or near-sight, where, by reason of the too great length of the ball, parallel rays come to a focus before reaching the retina, hence there is a diffused image produced there.

Hyperopia, or hypermetropia, or far-sight, where parallel rays, by reason of the abnormal shortness of the ball, have not come to a focus by the time they reach the retina, hence again there is a diffused image.

Astigmatism, where the curvature of the cornea or lens is greater in one meridian than in another.

simple myopic or hyperopic astigmatism :—
compound myopic or hyperopic astigmatism :—
mixed astigmatism.

Accommodation has for its object the changing of the thickness or convexity of the lens in order to adjust the eye to rays coming from varying distances.

It is brought about by the action of the *ciliary muscle*, called also the *tensor choroideæ*. By its contraction it draws forward the choroid, thereby relaxing the suspensory ligament of the lens, which is attached to it, thus allowing the lens to assume a greater degree of convexity by virtue of its own elasticity.

In a state of rest the lens is flattened by the tension of the suspensory ligament; is therefore accommodated for distance, or parallel rays.

Accommodation for near objects is accompanied by contraction of the pupil. When distant objects are looked at the pupil dilates.

"Near point" is the nearest point at which the eye can clearly see an object.

"Far point" is the farthest point at which an eye can see an object.

Error of accommodation.

Presbyopia, (old sight).

Correction of errors of refraction is made by spherical concave glasses for myopia; convex, for hyperopia; and for astigmatism by cylindrical (alone or with spherical); either concave or convex, or both, according as it is myopic or hyperopic or mixed.

Correction of errors of accommodation is made by means of convex glasses, either alone, or added to convex, or subtracted from concave.

Field of Vision,—the surface of the retina capable of receiving impressions projected externally.

Really co-extensive with the surface of the retina, projected outward; but to the mind it has no determinable limits, sometimes appearing smaller through a hollow body of small capacity, large when we look at a landscape through a window, and still larger when we have no limitation by near objects. (Perimeter.)

Inversion of the images on the retina.

Estimation of *size and distance*, though dependent upon the size of the "visual angle," assisted by the angle of convergence, is largely a matter of educated judgment.

Estimation of *direction* depends upon the part of the retina impressed, and its distance from the central point.

Estimation of *form and solidity* is attained by the mind from association of ideas, and from its power of superimposing, as it were, the two different superficial images presented simultaneously. (Stereoscope, Pseudoscope).

Clearness of vision, aside from accommodation, depends upon the number of rods and cones impressed.

Motion is given by the excitation of successive portions of the retina, and by the movements of our eyes in following an object.

(Vertigo, sensation of motion, when both object and eye are fixed).

(Subjective sensations. Hallucinations. Illusions. Entopic images.)

COLOR SENSE.

Color is not objective, but is due to a wave of light of definite length passing into the eyes with a certain velocity.

White light, the most complex of mixed colors, is decomposed by a prism into the 7 colors of the *spectrum*, of different wave-lengths.

The red rays (heat rays) at the one end, the violet (chemical rays) at the other. Beyond each end there are ultra-spectral rays, not cognizable by our senses.

Colors differ from each other—

- in tone or hue, *e. g.* red, green, etc.;
- in degree of saturation, *i. e.* amount of admixture with white light;
- in intensity, *i. e.* amount of light coming from unit area of colored object.

By mixing three standard spectral colors in various proportions we can produce not only the sensation of white light, but that of every color of the spectrum.

Hence three standard sensations, either because the retina cannot respond to more, or because the central apparatus cannot.

Theories of color sense.

Young-Helmholtz.
Hering.
Franklin, C. L., Mrs.

Young Helmholtz theory that in the retina there exist three substances capable of being affected by red, green, and violet rays respectively: all other color sensations produced by simultaneous affection of two of these substances in varying proportions. A blue ray stimulates violet- and green- perceiving substances, producing a sensation intermediate between the two, blue; red- and green- substances stimulated, produce sensations corresponding to yellow and orange. Each of the three substances are affected to a slight degree by all the rays of the visible spectrum.

All are equally affected, either by very small or very intense light, or where it falls on the extreme lateral portions of the retina.

Hering's that retina contains three substances in which chemical changes may be produced by other vibrations, but each affected in two opposite ways by rays of light which correspond to complementary color sensations. Thus in one substance, viz., the white-black -katabolic changes are produced by all rays of the visible spectrum, the maximum effect by the yellow, while anabolic changes occur where no light falls upon the retina: hence we have luminosity as distinguished from color. In a second substance red rays produce katabolic, and green anabolic, while a third is similarly affected by the yellow and blue rays; hence we have the red-green, and yellow-blue visual substances.

Franklin's, (Mrs. C. L.)—The eye in its earlier periods of development is sensitive only to luminosity, not to color—*i.e.* possesses only a grey-perceiving (white-black) substance, affected by all visible rays, but most powerfully by three near the middle of the spectrum. Sensation of grey is supposed to depend upon chemical stimulation of the nerve terminations by some product of decomposition of this substance.

In course of development a portion of this grey visual substance becomes differentiated into three different substances, each of which

is affected by rays corresponding to one of the three fundamental colors—red, green, and blue. When a ray of light intermediate between two of the fundamental colors falls upon the retina, the visual substances corresponding to these two colors will be affected to a degree proportionate to the proximity of these two colors to that of the incident ray. When the retina is affected by two or more rays of such wave-lengths that all three of the visual substances are equally affected, we have grey or white.

The power of the retina to distinguish colors diminishes from the centre towards the periphery; red is lost at a short distance from the macula lutea, while blue only at the extreme lateral portions of the retina.

With the perimeter a white object is seen over a wider field than
a colored object;
a blue over a wider field than a red;
and a red over a wider field than a green.

The exact shape, as well as size of the visual field differs somewhat for different colors.

Color-blindness, or *Daltonism*. (Methods of testing.)

Found in about 4 p. c. of all males, and only $\frac{1}{10}$ p. c. in females.

Fall into two classes: (Stewart.)

I. Green blind, where the whole spectrum, from red to yellow, is described as yellow of different degrees of intensity; the green appears as a pale yellow, with a grey or white band in its midst; the violet end is seen as different shades of blue.

II. Red blind, where the whole spectrum from red to green, is seen as green of different intensities, the extreme red being entirely invisible. The violet end is blue.

The brightest part of the spectrum is to the normal and to the green-blind the yellow;—to the red-blind it is the green.

From cases of hemianopia for colors it seems probable that there exists in the cerebral cortex a centre for color-sense, distinct from the visual centre.

Visual Sensations.

Light is the normal agent in the stimulation of the retina, and the rods and cones the only layer capable of reacting to this stimulus. (No rods in fovea centralis.)

(The rods differ from the cones:

they are color-blind. They produce a sensation of simple luminosity, whatever be the wave-length of the ray falling upon them;

more easily stimulated than the cones, and are particularly responsive to rays of short wave-length;

they have the power of adapting themselves to light of varying intensity.)

The luminosity of a faint object is greatest when we look not directly at it (where the cones are most numerous) but when we look a little to the one side of it (when the rods are chiefly stimulated.) VonKnis.

The rods and cones point away from the light towards the choroid and dip down into the layer of pigment cells. In these two layers (rods and cones and pigment) the vibrations are changed into nerve force which is then transferred by the optic nerve to the centre in the occipital lobe, where they are transformed into sensations of light, color, and form.

Duration of visual sensations.

The effect upon the retina always lasts about ⅛ second, no matter how brief the luminous impression.

Intensity of visual sensations, depends upon the luminosity, but is not directly proportioned to it.

"Visual purple," purple of Boll, or rhodopsin, is purple pigmentation of the outer limits of the retinal rods, formerly thought to aid in vision by chemical changes induced in it by the action of light.

But it is absent in the cones and in the macula lutea where the vision is best.

After images, from persistent excitation of the retina after the light object has been removed:

positive, if of similar brightness and color,—

negative, if of contrasting brightness or color.

Contrast.

Inverted images are thrown on the retina, by the bi-convex lens, but these are interpreted by the brain, into correct images.

(Mirror writing.)

Movements of the eye-balls.

Every movement, except truly transverse rotation, requires more than one pair of muscles.

The superior oblique rotates the pupil downward and outward, and assists the inferior rectus.

The inferior oblique rotates the pupil upward and outward, and assists the superior rectus.

Strabismus. Insufficiency, of the muscles.

Diplopia.

Argyll-Robinson pupil is where, on account of some nervous disturbance, the pupil does not contract to light, but does, when accommodation is exercised.

Nystagmus is a horizontal, vertical, or rotary oscillation of the balls, due (Gowers) to faulty fixation by the reflexes which normally keep them steady.

Hemianopsia or *hemiopia*, where only one-half of an object is seen. The division is vertical. The blind part of the retina is on the opposite side to the lost half of the object.

Binocular Vision. The inner portions of the optic nerve fibres decussate at the commissure, the outer portions do not.

SECTION XII.

THE REPRODUCTIVE FUNCTION.

The function of reproduction is that by which the species is preserved, in all higher animals, by means of the organs of generation.

(Regeneration of certain parts by cells; reproduction of a whole plant from a part, etc.)

CHAPTER I.—GENERATIVE ORGANS IN THE FEMALE.

The ovaries, (the essential part), whose function is the formation of ovules: Fallopian tubes, one connected with each ovary, to conduct the ovules, or the impregnated ovum to the uterus: the uterus, in which, if impregnated, the ovum is retained during its development, until fitted to maintain an independent existence: the vagina, with its external appendages, furnishing the means of communication between the internal organs and the external parts.

The **Ovaries** are each about 1½ inches long, ¾ inch wide, and ½ inch thick: enclosed in a dense fibrous tissue, (*tunica albuginea*), enfolded in the broad ligaments. They are attached to the uterus by a narrow fibrous cord, the ligament of the ovary, and more slightly to one of the fimbriæ of the Fallopian tubes.

The inner soft fibrous stroma contains embedded in it numerous vesicles, in various stages of development, called *Graafian vesicles*, or *follicles*.

These vesicles gradually approach the surface of the ovary until they project above it. Each one has an external covering = *membrana propria*, lined with a kind of epithelium of nucleated cells = *membrana granulosa*, and enclosing a nucleated mass of protoplasm, the *ovule*. These cells of the membrana granulosa are heaped up at one part of the follicle, around the ovule = *discus proligerus*, while the rest of its cavity is filled with a yellowish, alkaline albuminous fluid.

The **ovule,** or **ovum,** $\frac{1}{120}$ inch in diameter, has an external investment = *zona pellucida*, or *vitelline membrane*.

Within this is contained the yelk, or *vitellus*, consisting of granules and glubules of various sizes, embedded in a more or less fluid substance.

In the yelk, eccentrically placed, is the *germinal vesicle*, or *vesicula germinativa* consisting of a fine transparent, structureless membrane, containing a clear watery fluid, in which are a few granules.

At the part nearest the periphery of the yelk is the *germinal spot* (*macula germinativa*), of a finely granulated appearance and yellowish color.

(The ovum represents a typical cell.

The **Fallopian tubes,** 4 in. in length; open at their outer extremity into the cavity of the abdomen; (frimbriæ); extend from the upper angles of the uterus to the ovaries. Externally invested with the peritoneum, internally lined with ciliated epithelium, moving towards uterus; their walls composed of fibrous tissue and unstriped muscular fibres, chiefly circular.

The **uterus,** pyriform in shape, 2½ in. to 3 in. in length, 2 in. in breadth at the upper part, and ½ in. at the lower part.

(*Fundus. Cornua. Os internum; cervix; os externum.*)

Lined with columnar ciliated epithelium, extending to interior of the tubular glands.

Peritoneum is absent from the front surface of the neck.

Three coats of unstriped muscular fibres; a longitudinal, a circular, and an oblique and circular coat: (develope enormously during pregnancy. Very vascular.)

Glands, simple tubular.

Secretion alkaline.

In the cervix the mucous membrane is in longitudinal folds. The glands of tubulo-racemose type; glairy mucus; columnar epithelium.

The **Vagina,** 5-6 in. long, lined with squamous epithelium, and thrown into transverse folds, rugæ.

The walls of unstriped muscles and fibrous tissue, and a layer of erectile tissue.

Sphincter vaginæ at lower extremity.

External opening partially closed in virgins by a fold of mucous membrane,=hymen.

Glands: mucous follicles, and 2 vulvo-vaginal or Duverney's glands, (opening external to the hymen)—corresponding to Cowper's in the male.

External Organs:

clitoris;

labia minora, or *nymphæ* (2 folds of mucous membrane);

labia majora, or *externa*, or *pudenda*, (of integument lined with mucous membrane.)

CHAPTER II.—GENERATIVE ORGANS IN THE MALE.

Testes the essential secreting organs of reproduction in the male—1½ in. in length; enclosed in the scrotum.

Tubuli seminiferi make up the parenchyma of these compound tubular glands, and are loosely arranged in lobules between connective tissue septa. In embyronic life they are solid cords of cells, and remain in this embyronic condition until puberty. In the adult they become tubes with several layers of epithelial cells, seminal cells, mother-cells, and daughter-cells or spermatoblasts.

The ducts of the testes comprise a succession of tubes of different morphological and physiological values.

They are approximately 25 feet in length, and are named in order:

tubuli recti, rete vasculosum, vasa efferentia, canal of the *epididymis, vas deferens*, and *ejaculatory duct*.

The tubuli recti and rete vasculosum are mere channels for the passage of spermatozoa.

The vasa efferentia and canal of the epididymis contain smooth muscular fibres in their walls, and are lined with ciliated epithelium, causing a movement outward.

The vas deferens, and its offshoot the seminal vescicle is more important physiologically. It is nearly 2 feet in length with a diameter of $\frac{1}{10}$ in. throughout nearly its entire course. Its walls contain a very thick unstriped muscular layer, of longitudinal and circular fibres. It is an important storehouse of semen, and the glands near its end furnish a part of the fluid of the semen.

The seminal vesicle is a branched diverticulum from the vas deferens, and its chief, if not only function is to contribute fluid to the semen; probably the greatest share.

The ejaculatory duct, on each side is a short thin-walled muscular tube, passing partly through the substance of the prostate, and serving to convey the semen to the urethra.

The *urethra* contains in its walls longitudinal and circular muscular tissue, and except at its external opening, the small racemose glands of Littré.

The *prostate gland* is a compound tubular gland, whose alveoli are mingled with a large quantity of plain muscular tissue.

Its function is to contribute fluid to the semen (specific use unknown), which it does by numerous small ducts about the openings of the vasa deferentia.

Cowper's glands, two in number, are tubulo-racemose glands, the ducts of which open into the spongy portion of the urethra by two orifices some two inches below the openings of the vasa deferentia. Specific function of its viscid secretion unknown.

The Penis consists essentially of three long cylindrical bodies, the two *corpora cavernosa* side by side above, and the *corpus spongiosum* in the middle below, pierced throughout by the urethra. Consists mainly of erectile tissue. The corpus spongiosum terminates anteriorly in the *glans penis*.

Semen consists of *spermatozoa*, together with fluid and dissolved solids coming partly from the testes themselves, but chiefly secreted by the accessory sexual glands.

It is a whitish viscid alkaline fluid with a characteristic odor, containing,

Water (approximately 18 p. c.), and solids, viz., nuclein, protamine, proteids, xanthin, lecithin, cholesterin, and other extractives, fat, N. and K. chlorides, sulphates and phosphates.

(Charcot's crystals, (colorless), are a phosphate of a nitrogenous base, called spermine, contributed by the prostate.)

The secretion from the accessory glands has been shown to be essential to the mobility of the spermatozoa.

Spermatozoa are formed from the seminal cells lining the seminal tubules, of which two kinds; the *mother-cells*, dividing into *spermatoblasts*, from which the spermatozoa are formed.

Produced in large numbers; Lode computes 226,257,000 per week; within the male genital organs capable of living for months.

Outside the body they have been kept alive and in motion for forty-eight hours; have been found in the os uteri more than eight days after their discharge.

The spermatozoa are slender delicate cells, $\frac{1}{1000}$ inch in thickness, modified for locomotion and entrance into the ovule. It is the active element in fertilization, and is not burdened with a mass of food substance in its protoplasm. The nucleus is the fertilizing agent, contained in the *Head*. This is flattened, egg-shaped, with a thin anterior edge, terminating in a slender projecting and sharply pointed thread or spear, fitted for facilitating entrance into the ovule. Chief component seems to be *chromatic substance*.

The *middle-piece* is a short cytoplasmic rod, probably containing a centrosome.

The *Tail* is a delicate filiform, apparently cytoplasmic structure, and analagous to a single cilium of a ciliated cell, tipped by an exceedingly fine filament, the *end-piece*.

The most abundant solid chemical constituent of the spermatozoon is nuclein, probably in the form of nucleic acid, which is found in the head.

Movement is effected by the lashing of the tail from side to side accompanied by a rotary movement on its longitudinal axis ; at the rate of about 1.2 to 3.6 mm. per minute.

Menstruation.

In lower animals, the phenomena of "heat," "rut," and "œstrus."

Regarded as the sign of sexual maturity in the female, occurring in temperate climates usually at the age of 14 to 17 years, varying with food, growth, and environment. May begin in infancy, or later than puberty, and has been absent in otherwise normal women, in whom conception has taken place.

Normally ceases during pregnancy and lactation. Complete removal of the ovaries seems to put an end to the process of menstruation. Its natural final cessation, which is a gradual process, marks the *climacteric*, or *menopause*, at the end of sexual life, at the age of 45 to 50 and later, with wide variations.

Menstruation is marked by the discharge, about every 28 days, of a bloody, mucous fluid through the vagina, consisting of blood, epithelium and a portion of the mucous lining of the uterus.

It is attended by marked phenomena in other parts of the body, dependent mainly upon vascular turgescence and nervous tension.

It is a highly developed inheritance from our mammalian ancestors, which, under the influence of civilization and social life, has largely lost its technical sexual significance, although primarily a reproductive phenomenon derived directly from the lower females.

Its relation to ovulation not yet decided ; both are probably conditioned by the same cause, the menstrual congestion, yet either may occur without the other.

The rupture of a follicle may take place before, or at the beginning, more rarely at the middle or end of menstruation.

Puberty.

The approach of *puberty* in the female is marked by rounding of the form, increase in size of the mammæ and mental and nervous phenomena.

The *corpus luteum* is developed at the time of the rupture of the follicle, as a growth from the membrana granulosa, disappearing quickly when impregnation has not taken place, but in pregnancy, lasting nearly to end of gestation.

The approach of puberty or sexual maturity in the male, is marked by increased growth of hair on the pubis and face, by change of voice, dependent upon the growth of the larynx and lengthening of the vocal cords, and by increase of vital capacity.

It occurs at the age of fourteen to sixteen, and the formation of seminal fluid has been observed up to old age.

CHAPTER III.—THE REPRODUCTIVE PROCESS.

The essential part is the fusion of the pro-nuclei of the two germ-cells, which remain unmodified, and both morphologically and physiologically equivalent down to the time of their fusion. The modifications taking place during their maturation concern only the cell-protoplasm, (cytoplasm and centrosome). (Extension of the two polar bodies from the ovum.)

The act of copulation is rendered possible by the action of reflex centres in the lumbar region of the spinal cord, and by higher centres in the brain, causing marked vascular phenomena, accompanied by complex nervous and muscular activities. By it the semen is ejected into the neighborhood of the os uteri, whence the spermatozoa, by their own active movements, work their way into the uterus, and into the Fallopian tube, in the upper end of which they usually meet the ovule. The time occupied in this passage is probably short, but unknown. If ovulation has not taken place they perish.

Fertilization.

During maturation both the ovum and the spermatozoon have lost one-half of the chromosomes of their nuclei. The process of fusion of these two matured cells is called fertilization or impregnation.

For some unknown reason in most cases only one spermatozoon penetrates the ovule, and the rest ultimately perish. (Chemical attraction? as malic acid in female ferns attracts the spermatozoids.)

The *sperm-nucleus* finally reaches the *egg-nucleus* and its chromatin enters into the latter and the two fuse together and form a new

and complete nucleus, called the "*first segmentation nucleus*," the chromatin substance of which is now restored to the original amount present in each cell before maturation, but one-half is derived from the male, and the other half from the female cell. On the commonly accepted theory that this is the hereditary substance, the first segmentation nucleus contains within itself all the inherited qualities of the future individual, potentially.

Multiple conceptions.

Frequency of twin births varies in different countries. (In Prussia 1.12 p. c. ; in the cities of New York and Philadelphia 0.83 p. c.)

Twins may arise from separate ova (then a double chorion), or from a single ovum (a single chorion).

The two ova may come from a single Graafian follicle, or from two follicles within one ovary, or from both ovaries, and are both fertilized at approximately the same time.

There are two amnions, and the two placentas may be fused into one or be wholly separate.

The two offspring may be of different sexes, and need not closely resemble each other.

Two embryos from a single ovum may arise from the presence of two nuclei within the ovum, or be due to a mechanical separation of the blastomeres after the first cleavage or later in segmentation (as may be produced in various invertebrates and low vertebrates.) Their offspring are uniformly of the same sex and their resemblance to each other is always very close.

Triplets occur in Prussia 1 in 7,910 (0.012 p. c.), and quadruplets 1 in 371,126 births. Authenticated cases of quintuplets have been recorded. In all these cases a single ovum rarely, if ever, contributes more than two embryos, and these are characterized, as in the case of twins, by being of the same sex, by possessing a single chorion, and by close personal resemblance.

(Super-fecundation = the fertilization of two ova at the same menstruation, by two different acts of coition. A white and a black child have been born as twins.

Superfœtation = second impregnation at a later period of pregnancy, as is in the second or third month. Only possible where there is a double uterus or when ovulation (menstruation?) persists until the time of the second impregnation.)

[Hybrids, in animals, produced by a cross between different species. Most male hybrids sterile, female fertile with the male of

both parents, but the characters of the offspring tend to return to those of the species of their parents.]

Heredity.—Inheritance of acquired characteristics: of diseases. Variations. Reversion or Atavism. Theories.

Determination of sex.

In most civilized races more boys are born than girls.

Influences which determine sex in any one individual not known. The sexual organs in the embryo well differentiated at eighth week of intra-uterine life, hence sex must be settled previously. Germ-cells probably asexual.

Various theories: Hofacker-Sadler law that sex depends upon relative age of the parents: Thury's, upon the time of fertilization after liberation of the ovum;—Düsing's extends this to the male element, the younger the spermatozoon the greater the tendency to production of males;—Schenk's nutrition-theory.

Statistics among mammals and human beings indicate that the proportion of male to female offspring varies inversely with the nutrition of the parents, especially of the mother, *e. g.* more boys born to poor than to prosperous families. (Seemingly corroborated by experiments made with plants, insects, and higher animals.)

Cell division is largely, if not wholly, indirect or karyokinetic, although the term segmentation or cleavage is conveniently applied to the first few divisions, whereby the murula or mulberry mass is produced, during the passage of the ovum through the Fallopian tube, occupying about eight or ten days.

From the accumulation of cells at the periphery of the yelk—where, from pressure, they gradually assume a polyhedral shape,—is formed the *blastodermic membrane.*

The 3 layers of this are the epi-meso- and hypo-blast.

Development of the ovum.

The *germinal area*, at first round then pyriform, is the position at which the embryo is about to appear.

In the centre of this area a clear transparent spot developes, which is called the *area pellucida*—around this is the *area opaca.*

Near the back part of the area pellucida appears a shallow longitudinal groove, which is the first trace of the embryo, and is called the *primitive groove.* This is soon replaced by a more permanent groove, beginning at the anterior part of the area pellucida, called the *medullary groove.*

Laminæ dorsales are the longitudinal elevations which bound the groove, and finally convert it into a canal, the primitive cerebro-spinal axis, or neural tube This closing in begins at the neck, then the head and then down to the lower extremities.

The *chorda dorsalis*, or *notochord*, is an aggregation of cells from the mesoblast immediately beneath or back of the neural canal, extending nearly the whole length of the canal, and occupying the position of the future vertebræ.

The *proto-vertebræ* are square segments, composed of cells from the mesoblast which appear on both sides of the neural canal, its whole length.

Outside of the protovertebræ, by the "splitting of the meso blast," two laminæ are formed, the parietal and the visceral. The parietal lamina is closely connected with the epi-blast, constituting the *somatopleure*, which goes to form the body wall and muscular walls of the alimentary canal, and other parts. The visceral lamina unites with the hypoblast, and constitutes the *splanchnopleure*, which forms the pericardium, the pleuræ and the peritoneum. Between these two lies the pleuro-peritoneal cavity.

Gradually the blastoderm is tucked in under the head and tail extremities of the embryo, forming the *head and tail folds*.

Similar folds mark off the lateral margins of the embryo which thus is entirely separated from the yelk (umbilical vesicle), and surrounded by a clear space on all sides, but the anterior or ventral side still communicates with the yelk. This communication is gradually narrowed down to a mere pedicle which passes out of the body at the point of the future umbilicus.

The downwardly folded portions of the blastoderm are the visceral plates.

The rudimentary alimentary canal, formed by the folding of the splanchnopleure lined by hypoblast, is closed at both ends, while the centre communicates freely with the cavity of the yelk sac, through the *vitelline* or *omphalo-mesenteric duct*.

The portion of the yelk sac outside the body cavity is called the *umbilical vesicle*, which affords nutriment to the embryo, through the omphalo-mesenteric vessels which ramify in the walls of the yelk sac. This lasts only a short time in mammalia, the nourishment soon being derived from the mother.

Amnion.

Beyond the head and tail folds the somato-pleure, coated by

epiblast, rises in folds, anteriorly, posteriorly and laterally, all converging to a point above the dorsum of the embryo.

These folds come together and coalesce; the inner layer forms the true amnion, and the outer, which coalesces with the original vitelline membrane, constitutes the false amnion.

The *chorion* is partially formed by this coalescing of vitelline membrane and the false amnion.

The cavity between the true amnion and the external surface of the embryo becomes a closed space, the amniotic cavity, which gradually becomes filled with fluid; the amniotic fluid.

Allantois.

This is a highly vascular, at first solid growth, of the splanchnopleure, from the hinder portion of the peritoneal cavity, which insinuates itself between the two amniotic folds, and comes in contact with the outer fold, (the false amnion), in mammals in one spot, in birds all over, forming the chorion. At this one spot, by the interlacing with the vascular system of the mother, the *placenta* is developed.

As the visceral layers close in the abdominal cavity the allantois is divided, at the umbilicus, into two portions; the outer part extending from the umbilicus to the chorion, (which forms fœtal portion of the placenta,) is the cord, and is cast off after birth. The inner part is in part converted into the urinary bladder, and the urachus, extending from the bladder to the umbilicus. This urachus remains as an impervious cord stretched from the top of the bladder to the umbilicus, in the middle line of the body, and is sometimes called a ligament of the bladder.

The *villi of the chorion* are small vascular processes which develop on its surface, and form the fœtal part of the placenta.

During these changes the whole mucous membrane of the uterus becomes much more vascular, thicker and softer, the follicles become tortuous and enlarged, while the epithelial layers increase in amount. This constitutes the *decidua vera*, lining the cavity of the uterus.

The *decidua reflexa* grows up around the ovum and forms an investment for it; by the third month coming in contact with the decidua vera, and no longer being distinguishable from it.

The *decidua serotina* is that part of the vera which becomes especially developed in connection with those villi of the chorion which remain to form the fœtal part of the placenta, itself forming the maternal part of the same.

The **placenta** is the organ by which the gaseous and nutritive interchanges take place between the maternal tissues and the embryo.

There is no direct communication between the blood-vessels of the mother and those of the fœtus. The villi of the chorion, containing fœtal blood-vessels, push the thin walls of the sinuses formed in the deeper layers of the uterine mucous membrane before them, and thus come into intimate relation with the blood contained in them. The thin membranes intervening between the blood of the one and of the other, allow of a free interchange of matters between them by diffusion and osmosis. The maternal sinuses communicate on the one hand with arteries, and on the other with veins of the uterus, while there is a constant stream of blood into and out of the loop of capillary blood-vessels in the villi.

By this arrangement the fœtus is furnished with nutritive materials, and gets rid of excrementitious products.

The greater part of the placenta is thrown off as the "after-birth," immediately after birth; the remaining part withers and gradually disappears by being absorbed or thrown off in the uterine discharges as the *lochia*, which occur at this period. A new mucous membrane is formed.

At the close of pregnancy the placenta is 7–8 inch in length, 6–8 inch in breadth.

The **umbilical cord,** in the latter part of fœtal life, consists almost entirely of two arteries and a single vein, with the remnants of the structures which in an earlier stage were of great comparative importance, viz.: externally a layer of the amnion; the umbilical vesicle, with its duct and omphalo-mesenteric vessels; the remains of the allantois, and, continuous with it, the urachus.

It appears at the end of the first month, and gradually increases in length, until at the end of gestation it measures about 20 inches.

(Although the phenomena of *Pregnancy* and *Parturition* are strictly physiological, they are outside the limits of a course of lectures on physiology.)

At birth great changes take place in the circulation of the infant, intimately connected with the commencement of the respiratory activity of the lungs.

The causes of the first respiration are:

(1) The *increasing venosity of the blood*, circulating in the medulla, which stimulates the respiratory centre when the umbilical cord has been cut or tied and the placental circulation thus interfered with;

(2) the *stimulation of the skin* by the air, which acts reflexly upon the respiratory centre.

With the first breath the new being begins its independent existence.

DEATH.

Normally after a period of increasingly marked senescence, characterized by somatic atrophy and degeneration, a period is reached when vitality must cease and the change called death must come.

Molecules of living matter are being disintegrated and whole cells are dying and being cast off constantly throughout life (*cellular death*), but when one or more of the organic functions is so disturbed that harmonious activity of all the functions becomes impossible *somatic death* occurs.

The nervous system dies almost immediately with the cessation of individual life. The right auricle is the last part to die, (the *ultimum moriens*, Harvey). Gland-cells die in a few minutes. For many minutes after death the heart muscle if exposed will respond to single stimuli. In the unstriped muscles of the stomach and intestines the irritability is said to continue for forty-five minutes, and considerably longer in the striated muscles of the limbs. Within 15 to 20 hours the body cools to the temperature of the surrounding medium. After the rigor mortis (*q. v.*) has passed off the tissues soften and putrefactive changes begin.

The germ-cells, both male and female, that are employed in the production of new individuals cannot be said ever to undergo death ; they pass from parent to offspring. According to Wisemann's theory primitive protoplasm was not endowed with the property of death. (Amœbæ.) With the progress of evolution the cells of the individual body have become differentiated into somatic cells and germ-cells, the former growing old and perishing, the latter passing from parent to child, never dying, immortal.

SECTION XIII.

DEVELOPMENT OF THE EMBRYO.

FROM THE EPIBLAST ARE DERIVED:

the whole nervous system, including, brain, cord, peripheral and sympathetic nerves;

the epithelial structures of the organs of special sense;

the epidermis, including hair and nails;

the epithelium of all the glands opening upon the skin, including the mammary, the sweat and the sebaceous glands;

the epithelium of the mouth, (except that covering the tongue, and the adjacent posterior part of the floor of the mouth, which is from the hypoblast)—and that of glands opening into it;

the enamel of the teeth:

the epithelium of the nasal passage; of the adjacent upper part of the pharynx; and all of the cavities and glands opening into the nasal passages.

FROM THE MESOBLAST ARE DERIVED:

the urinary and generative organs, (except the epithelium of the bladder and urethra);

all the voluntary and involuntary muscles of the body (except the muscular fibres of the sweat glands);

the whole of the vascular and lymphatic systems, including the serous membranes and spleen;

the skeleton, and all the connective tissues and structures of the body.

FROM THE HYPOBLAST ARE DERIVED:

the epithelium of the alimentary canal, from the back of the mouth to the anus, and that of all glands which open into this part of the alimentary tract;

the epithelium of the Eustachian tube, and tympanum;

the epithelium of the bronchial tubes and air cells of the lungs;

the epithelium lining the vesicles of the thyroid;
the epithelial nests of the thymus;
the epithelium of the urinary bladder and urethra.)
(Kirke, from Schaefer, after Quain's Anatomy.

VERTEBRAL COLUMN AND CRANIUM.

The *chorda dorsalis*, or notochord, is the primitive part of the vertebral column in all mammals, but is permanent in but few animals.

The *protovertebræ* send processes downward and inward to surround the notochord, and upward between the medullary canal and the epiblast covering it. In the former situation the cartilaginous bodies of the vertebræ make their appearance, and in the latter their arches, which enclose the neural canal.

Each vertebra is developed from the contiguous halves of two protovertebræ. The ganglia of the spinal nerves thus become joined to the posterior part of the vertebræ to which they belong.

A new segmentation of the protovertebræ occurs so that a permanent *intervertebral disc* is developed opposite the centre of each, while they themselves split into a dorsal and ventral portion.

From the dorsal, called the *musculo-cutaneous plate*, are developed all the muscles of the back, with the cutis of the dorsal region, (the epidermis coming from the epiblast); from the ventral portion arise the *vertebræ* and the *heads of the ribs*.

In connection with the vertebræ in the dorsal region processes grow out horizontally as the rudiments of the ribs.

The chorda gradually atrophies, and is finally represented only by a mass of soft cells in the centre of an intervertebral disc.

The true *cranium* is a prolongation of the vertebral column. Originally it forms but one mass, a cerebral capsule, the chorda dorsalis being continued into its base and ending there in a tapering point.

At an early period the head is bent downward and forward around the end of the chorda, so that the middle cerebral vesicle, and not the anterior comes to occupy the highest position in the head.

CRANIUM.

The brain-case consists of three segments, occipital, parietal, and frontal, corresponding in their relative positions to the three primitive cerebral vesicles, and in front of each segment is developed a sense-organ (auditory, ocular, and olfactory).

The pituitary body, is formed by the meeting of two outgrowths, one from the fœtal brain, which grows down, and the other from the epiblast of the buccal cavity, which grows up towards it. The secondary mesoblast also takes part in its formation. The connection of the first process with the brain becomes narrower, and persists as the infundibulum, while that from the buccal cavity disappears entirely at a spot corresponding with the future position of the sphenoid bone.

The Basis Cranii, (base of the cranium) consists at this time of an unsegmented cartilagenous rod, developed around the chorda dorsalis, in which three centres of ossification appear,

basi-occipital,
basi-sphenoidal,
and presphenoidal, corresponding to each segment.

They ultimately become the basilar process of the occipital bone, and the body of the sphenoid.

The bones forming the *vault of the cranium*, viz., the frontal, parietal, squamous portion of the temporal and the squamo-occipitals are ossified in membrane.

The entire *skeleton* is at first either membranous or cartilaginous, and ossification proceeds from centres of ossification, beginning in the second month, in the jaws, and clavicle.

The Extremities are developed in a uniform manner in all vertebrates. They appear as leaf- or bud-like elevations from the sides of the trunk, the primitive form being the same whether intended for swimming, crawling, walking, or flying. In the human fœtus the fingers are at first united, as if webbed. The fore limb appears before the hind limb. In both limbs alike the distal segment is separated by a slight notch from the proximal part, and this part subsequently divided by a second notch, the knee and elbow joints.

VISCERAL CLEFTS AND ARCHES.

As the embryo enlarges, the heart which, at first, lay near the cranial flexure, is carried further backward, until there is considerable space intervening between them ; this becomes the neck.

In the neck appear the **four series of branchial or visceral clefts** across the axis of the gut, not quite at right angles ; the anterior being formed first.

The anterior border of each cleft forms a lip or fold, — the *branchial or visceral fold.*

The posterior border of the last cleft is also formed into a fold so that there are four clefts and five folds, but the three most anterior are the most prominent, and of these the second is the most conspicuous.

The first fold nearly meets its fellow in the middle line forming an "arch" the second less nearly, and the others still less so. Thus in the neck there is a triangular interval, into which, by the splitting of the mesoblast at that part, the peritoneal cavity extends.

The branchial clefts and arches are not permanent.

The *first arch* gives off branches from its opposing front edges, which pass forward to meet, but are prevented from doing so by a process which grows downward from the head (the *fronto-nasal process*) and with which they are united to form the *upper jaw*.

(Failure to unite causes "*cleft palate*," or where the integument presents a similar deformity, "*hare lip*." Frequently, but not necessarily, co-exist.)

The main folds uniting in the middle form the *lower jaw*, and superiorly the *malleus*.

Between the branches and the main first fold is the cavity of the mouth.

From the *second arch* are developed the incus, stapes, stapedius muscle, the styloid process of the temporal bone, the stylo-hyoid ligament and the smaller cornu of the hyoid.

The cleft between the first and second arches partially closes up, but there remains an opening at the side which becomes the Eustachian tube, tympanic cavity, and external auditory meatus.

From the *third arch* are developed the greater cornua and body of the hyoid bone.

In man and other mammalia the *fourth arch* is indistinct.

A distinct connection is traceable between the visceral clefts and certain cranial nerves, the trigeminus, facial, glosso-pharyngeal, and vagus.

THE ALIMENTARY CANAL AND APPENDAGES.

The alimentary canal is formed by the pinching off of the yelk-sac by the visceral plates as they grow downward and forward.

In the earliest stages it is a straight tube closed at each end and lying just beneath the vertebral column.

It consists of three distinct parts, the fore-gut, the hind-gut, ending blindly at each end of the body, and a middle segment which

communicates for some time freely, on its ventral aspect, with the yelk-cavity of the yelk-sac, through the vitelline or omphalo-mesenteric duct.

From the fore-gut are formed the pharynx, the œsophagus and stomach.

From the hind gut, the lower end of the colon and the rectum.

The *mouth* is developed by an involution of the epiblast between the maxillary and mandibular (lower jaw) processes, which becomes gradually deeper until it reaches the blind end of the fore-gut, and at length communicates freely with the pharynx by absorption of the intervening partition.

The *anus*, at the other end, is formed, about the seventh week, by a similar involution from the free surface which at length opens into the hind-gut.

(When this union does not take place, by the absorption of the intervening structures, we have imperforate anus.

A similar condition may, though rarely, exist at the other, (mouth) end of the alimentary canal.)

The *middle portion of the canal* becomes more and more closed in, until finally, the original communcation with the yelk-sac becomes narrowed down to a small duct, the vitelline. This usually disappears in the adult, but occasionally the proximal extremity remains as a diverticulum from the intestine. Sometimes a fibrous cord, attaching some part of the intestine to umbilicus, remains to represent the vitelline duct, and has been known, in after life, to cause strangulation of the bowel and death.

The alimentary canal gradually increases in length and becomes convoluted, and also divided into its several parts, stomach, small and large intestines. At the same time it comes to be suspended in the abdominal cavity by means of a lengthening mesentery, formed from the splanchnopleure, which attaches it to the vertebral column.

The stomach originally has the same direction as the rest of the canal, but finally, undergoes change of position.

Salivary Glands and Pancreas.

Each salivary gland first appears as a simple canal with bud-like processes communicating with the mouth ; formed from the epiblast lining that cavity. As the development proceeds the canal becomes more and more ramified ; the branches, or salivary ducts, constituting a system of closed tubes.

The pancreas is developed in a similar manner, but from the hypoblast lining the intestines. Two small ducts bud out from the duodenum, divide and subdivide and thus form the glandular structure.

Liver, etc.

The liver is developed by a protrusion of a part of the walls of the fore-gut, in the form of two conical hollow branches which embrace the common venous stem. It grows very rapidly, and soon almost fills the abdominal cavity.

The hepatic cells are derived from the hypoblast which lines the intestine.

The connective tissue and blood-vessels are from the mesoblast.

The *gall-bladder* is developed as a diverticulum from the hepatic duct.

The *spleen*, *lymphatic* and *thymus glands* are developed from the mesoblast; the *thyroid* partly also from the hypoblast, which grows into it as a diverticulum from the fore-gut.

RESPIRATORY APPARATUS.

The lungs appear at first as two small diverticula from the abdominal surface of the œsophagus. They open at first directly into the œsophagus, but as they grow, a separate tube, the future trachea, is formed at their point of fusion, opening into the œsophagus on its anterior surface.

These primary diverticula of the hypoblast of the alimentary canal send off secondary branches into the surrounding mesoblast, and these again give off tertiary branches, the air-cells. Thus the epithelium lining the air-cells, the bronchi and trachea are derived from the hypoblast, and all the rest of the lung tissue, nerves, lymphatics, blood-vessels, cartilagenous rings, and muscular fibres, come from the mesoblast.

The lungs at first extend into the abdominal cavity, but become confined within the thorax by the development of the diaphragm.

THE GENITO-URINARY SYSTEM.

Bladder.

Is formed by the dilatation of that portion of the allantois remaining within the abdominal cavity on the closing in of this by the visceral plates.

It at first communicates with the intestine, but later with the exterior by the urethra. It is attached to the abdominal wall by the

urachus, a rounded cord, the remains of another portion of the allantois.

The Wolfian Bodies are peculiar to the embryonic state; temporary kidneys.

The *Wolfian duct* first makes its appearance as a cord running in the mesoblast, beneath the epiblast, longitudinally on both sides. It becomes hollowed into a tube, the Wolfian duct. From this tube secondary diverticula arise, extending into the surrounding mesoblast.

Tufts of vessels grow into the blind ends of these tubes, invaginating them and producing "*Malpighian bodies*," very similar to those of the permanent kidney; these constitute Wolfian bodies.

The ducts of each side unite into a common excretory duct which empties into the intestinal canal at a point opposite the allantois.

Part of the Wolfian duct, the metanephros, sends out a projection which grows rapidly and opens into the cloaca, and remains as the *ureter*.

From the upper part of this ureter arise convoluted tubules, at the end of each of which is developed a tuft of vessels which form a "Malpighian corpuscle," and from the grouping of these elements are formed the *kidneys*, consisting at first of a number of separate lobules.

Supra-renal bodies originate from the mesoblast, just above the kidneys, and are at first larger than the kidneys.

On the outer side of the Wolfian body appears another duct, **the duct of Mueller,** which also opens into the intestine.

Behind the Wolfian body a portion of the mesoblast projects in the form of a ridge, covered on its free surface with an epithelium, called the "*germ epithelium*."

From this projection is developed the reproductive gland, ovary or testis as the case may be.

According as the individual is male or female, one or the other ducts mentioned developes.

In the male the Wolfian duct remains as the vas deferens, epididymis, and seminal vesicles, while Mueller's duct atrophies.

In the female, the Wolfian duct and body atrophy, while Mueller's ducts approach one another, and unite along a certain distance at their lower extremities. Of the united part the upper end forms the *uterus*, and the lower the *vagina*, while the ununited parts form the *Fallopian tubes*, which become connected with the

ovaries, while their cavities remain continuous with the pleuroperitoneal space.

For some time it is impossible to determine whether an *ovary* or a *testis* will be developed from the germinal epithelium. Gradually (by the eighth week the sex is determined) the special characters belonging to one of them appear, and the organs assume a lower position, the ovaries being ultimately placed in the pelvis, while the testicles enter the inguinal rings in the seventh month of fœtal life, and reach the scrotum by the end of the eighth, taking with them a pouch of peritoneum, the *tunica vaginalis*, their serous covering. The communication between the tunica vaginalis and the peritoneum is closed only a short time before birth.

Both ovaries and testicles take with them the blood-vessels, nerves and lymphatics which are supplied to them while in the lumbar region.

(Congenital anomalies: double uterus or vagina; undescended testicles.)

External parts of generation are at first the same in both sexes.

The opening of the genito-urinary apparatus is in both cases bounded by two folds of skin, while in front of it is formed a *penis-like body*, surmounted by a glans, and with a cleft or furrow along its under surface. The borders of the furrow diverge posteriorily, running at the sides of the genito-urinary orifice internally to the cutaneous folds just mentioned.

In the female this body, becoming retracted, forms the *clitoris* and the margins of the furrow on its under side are converted into the *nymphæ* or *labia minora*; while the cutaneous folds constitute the *labia majora*.

In the male the margins of the furrow at the under side of the penis unite at about the fourteenth week, and form that part of the *urethra* which is included in the penis. (Hypospadias.)

The large cutaneous folds become the scrotum and later in the eighth month, receive the testicles which descend from the abdominal cavity.

(Congenital anomalies: hypospadias; hermaphroditism, with undescended testicles; unshrunken clitoris, etc.)

THE VASCULAR SYSTEM.

A number of branched cells in the mesoblast, send out processes which unite so as to form a network of protoplasm with nuclei at the

nodal points. These processes become hollowed out, giving rise to the capillary wall, composed of endothelial cells. In the walls of these branching canals rest embedded the nuclei, a large number of which acquire a red color, and form the red blood-corpuscles, and the circulation commences.

The Heart. About the same time the heart appears as a solid mass of cells of the splanchnopleure, beneath the posterior end of the fore-gut.

At first there is no distinct cavity, but soon the cells of the mesoblast within the mass forming the heart become transformed into blood-corpuscles, and thus the heart becomes hollowed out, at first probably into two primary tubes, which coalesce in the human embryo, to form a single cylinder, lined with endothelial cells, *the endocardium*.

Pulsations take place even before the appearance of a cavity, and immediately after the first development of the cells from which the heart is formed, and long before muscular fibres and ganglia have been formed in the cardiac walls. At first these pulsations seldom exceed 15 to 18 per minute. After a time the tubes show signs of division into three parts ; the upper part becoming the aortic bulb, next to which is the cavity of the ventricles, continuous with which is the auricular space.

The tube now becomes twisted on itself, the auricular part coming to be posterior and superior, while the ventricular, with the aortic bulb, remains anterior and somewhat below.

Each of the primitive cavities now becomes divided into two, by the gradual growth of partitions. The septum of the ventricles commences at the apex and extends upward : (begins at fourth week, complete in eighth).

The septum of the auricles is developed from a semilunar fold which extends from above downwards. (In man, and in all animals which possess it, this remains imperfect during fœtal life.)

The aortic bulb, or bulbus arteriosus, is gradually divided by an internal septum, taking a spiral direction, and separating the tube into the aorta, and the pulmonary artery.

The auriculo-ventricular and semilunar valves are formed by the growth of folds from the endocardium.

(Up to a certain time the auricular is larger than the ventricular division, but this is gradually reversed.)

(Congenital anomalies : failure in the completion of the various partitions and consequent communication between the cavities.)

Arterial system.

Around the pharynx are developed 5 *pairs of aortic arches*; commencing anteriorly from the 2 primitive aortæ, and, passing along the sides of the pharynx, they unite posteriorly to form the main aorta.

(These 5 are never present at the same time in the higher animals, for the two anterior pairs gradually disappear while the posterior ones are making their appearance, so that there are at length only 3 remaining.)

The 3rd aortic arch remains as the internal and external carotids.

The 4th arch on the left developes into the permanent aorta, while on the right it remains as the subclavian.

The 5th disappears on the right side, but on the left it forms the pulmonary artery.

The distal end of this arch originally opens into the descending aorta, and this arrangement remains during fœtal life as the ductus arteriosus. (In many reptiles, it is permanent through life, on both sides.)

As the umbilical vesicle diminishes in size the portion of the omphalo-mesenteric arteries outside the body gradually disappears, the part inside remaining as the mesenteric arteries.

With the growth of the allantois two new arteries (the umbilical), appear and rapidly increase in size, until they are the largest branches of the aorta. They are given off from the internal iliac, and for a long time are considerably larger than the external iliacs, which supply the comparatively small hind limbs.

Veins.

The chief veins of the early embryo are divided into two groups:

visceral, omphalo-mesenteric and umbilical;

parietal; jugular and cardinal.

The earliest to appear are the omphalo-mesenteric, or vitelline, which return the blood from the yelk-sac to the developing auricle. As soon as the placenta, with its umbilical veins, is developed, these unite with the omphalo-mesenteric, and thus the blood reaches the auricle, partly from the yelk-sac and partly from the placenta.

The right omphalo-mesenteric and right umbilical soon disappear, and the united left omphalo-mesenteric and left umbilical veins pass through the developing liver, and in this way to the auricle. The fœtal liver is thus supplied with venous blood from two

sources, through the umbilical vein and through the portal veins. At birth the circulation through the umbilical vein is completely shut off.

The blood is returned from the head by the two primitive jugulars, which unite with the cardinal veins, conveying the blood from trunk and lower extremities to form a vessel on each side called the duct of Cuvier.

As the kidneys develope, the renal veins unite and form the inferior vena cava, which receives branches from the legs (external iliac), and increases rapidly in size. Further up, too, it receives the hepatic veins.

The heart descends into the thorax, and causes the ducts of Cuvier to become oblique instead of transverse.

As the upper extremities develope, the subclavian veins are formed and join the jugulars.

A transverse communicating trunk now unites the two ducts of Cuvier; gradually increases and forms the left innominate; the left duct of Cuvier becomes obliterated, while the right remains in part as the right innominate, and partly with the right jugular forms the superior vena cava.

A transverse branch appears, whereby the blood is carried from the left cardinal vein into the right, and becomes the vena azygos minor, and the right cardinal vein becomes the azygos major.

THE CIRCULATION.

The primitive circulation of the human embryo may be divided into two, although they exist coincidently, and arise in connection with one another.

(a). **The earlier circulation** is that which is directed to the yelk sac; the embryo receiving nutriment from the vitellus or yelk.

This exists in man but a short time; about fifth or sixth week of fœtal life it ceases, the yelk being atrophied and the placental circulation established.

The aortic bulb is continuous with two vessels which run on either side of the primitive pharynx (= the aortæ), and from each one of which a large branch is given off. These omphalo mesenteric arteries pass to the yelk-sac and there become split up into a number of small vessels, the blood from these being returned partly by the corresponding omphalo-mesenteric veins, partly, by a large vein running round the periphery of the vascular area, — the *sinus terminalis*.

This sinus opens partly into the right and left omphalo-mesenteric veins, which subsequently unite into a common trunk, the *sinus venosus.*

(b.) **The later placental circulation** is developed in the mesoblastic layer of the allantois, when the blood-vessels of the allantois enter the chorion, the processes of which are embedded in the decidua of the uterus, where they come into close relation with the blood in the maternal vessels.

The course taken by the blood through the heart and vessels of the fœtus differs essentially from that which persists through adult life, but gives place to the latter immediately at birth.

FŒTAL CIRCULATION.

The arterial blood from the placenta to fœtus travels along the *umbilical vein* to the *liver.*

(Gives several branches to the left lobe.)

It divides into *two streams :*

- the larger, joining the portal vein, enters the liver and passes through the hepatic veins into the vena cava ascendens or inferior ;
- the smaller passes directly into the vena cava ascendens through the ductus venosus.

(In the vena cava the blood carried by the hepatic veins and ductus venosus mixes with the blood which has circulated through the lower extremities.)

On entering the *right auricle*, the blood of the *inferior* or *ascending vena cava* is directed by the Eustachian valve through the foramen ovale, into the left auricle, and thence into the left ventricle.

The left ventricle forces it into the aorta and thence it is distributed to the head and upper extremities, a small part only going into the descending aorta.

The blood from the head and upper extremities returns to the heart along the *superior or descending vena cava*, into the *right auricle*, right ventricle, and pulmonary artery.

A small part only of that in the pulmonary artery is conveyed to the unexpanded lungs, the greater part passing through the ductus arteriosus into the aorta at the commencement of its descending portion.

This blood is distributed to the lower extremities, a certain portion entering the *hypogastric arteries*, and being conveyed to the *placenta.*

Peculiarities. The greater part is submitted to the action of the liver.

The head receives the purest blood that enters the heart.

Changes at Birth.

When respiration begins, an increased quantity goes to the lungs.

The ductus arteriosus begins to contract soon after birth, and is completely closed from the 4th to 10th day.

The hypogastric arteries remain patent in their first part, as the superior vesicle arteries, but the portions between the bladder and umbilicus become obliterated from 2 to 5 days after birth, and remain as the true anterior ligaments of the bladder.

The ductus venosus, and umbilical veins become obliterated a few days after birth; the ductus venosus can be traced as a fibrous cord in the fissure of the same name on the under side of the liver, and the umbilical vein becomes the round ligament.

The foramen ovale is closed by the 10th day after birth, and the Eustachian valve is soon reduced to a mere trace.

THE NERVOUS SYSTEM.

The spinal cord is formed from that part of the medullary canal which lies over the chorda dorsalis.

The medullary canal is lined with columnar cells derived from the epiblast, which develope at the sides of the canal and decrease its lumen.

The lateral walls approximate and unite in the centre, thus converting the medullary canal into two separate tubes, a dorsal and a ventral one.

The lower, or ventral division becomes the central canal of the spinal cord; the columnar cells of the epiblast form a lining of ciliated columnar epithelium. The external surface gives rise to the *dura mater* and *pia mater*.

The epiblast at the lower part of the canal becomes converted into the anterior grey columns, in connection with which arise the *anterior roots of the spinal nerves*; while, at the upper part, the *posterior grey columns* are formed, in connection with the *posterior roots* and their ganglia.

The upper or dorsal canal becomes converted into a fissure by the absorption of its roof, and is thus changed into the *posterior fissure* of the cord.

The *anterior fissure* is formed by the downward growth of the anterior columns.

The primitive neural canal itself terminates posteriorly in an oval dilatation, and anteriorly in a bulbous extremity which soon becomes partially contracted, forming the **anterior, middle,** and **posterior cerebral vesicles**; from which are respectively developed ultimately the cerebrum, the corpora quadrigemina, and the medulla oblongata.

From the **anterior vesicle** spring at an early period, two processes, which become the optic vesicles, which ultimately develope into the retina and other nervons parts of the eye.

From the same anterior vesicle, somewhat later, spring two larger processes, at a higher level, upwards and backwards, constituting the *primitive cerebral hemispheres.*

The floor of these lobes thickens and forms the *corpora striata*, while the roof developes into the hemispheres proper.

The cavities of these lobes become the *lateral ventricles* and are connected by the *foramen of Monro*, which at first is very wide, but subsequently narrows to a mere slit.

The cerebral hemispheres are separated at an early period by a fold of connective tissue, which ultimately forms the *falx cerebri.*

The hemispheres greatly enlarge in a backward direction so that they overlap the thalamencephalon (the hinder part of the anterior brain), and the parts developed from the middle cerebral vesicle.

The *corpus callosum* is later formed by the fusion of the juxtaposed parts of the hemispheres.

From the anterior part of the cerebral hemispheres arise two prolongations which develop into the *olfactory bulbs*; these grow forward, and soon lose their cavities, which at first communicated with those of the ventricles.

(The parts of the anterior brain thus far described are called, as a whole, the prosencephalon; the hinder part is the thalamencephalon.)

The cavity of the thalamencephalon opens behind into the cavity of the middle cerebral vesicle, and in front communicates with the hollow rudiments of the cerebral hemispheres, and eventually becomes the cavity of the *third ventricle.*

The floor of the thalamencephalon is developed into the optic chiasm, part of the optic nerve, and the *infundibulum*

The latter comes in contact with a process from the mouth, uniting with which, it ultimately forms the *pituitary body*.

From the posterior part of the roof of the thalamencephalon is developed the *pineal gland*, a peculiar outgrowth of unknown function.

The anterior part of the roof becomes very thin, and its place is finally occupied by a thin membrane containing a vascular plexus which persists in the roof of the third ventricle, the *choroid plexus*.

From the sides of the thalamencephalon, are developed the *optic thalami*.

Middle Cerebral Vesicle.

By the bending downward of the brain at the junction of the first and second cerebral vesicles, the second comes to be the most anterior part.

The upper walls of the middle vesicle are developed into the *corpora quadrigemina*.

From the lower wall arise the *crura cerebri*.

The cavity of this middle vesicle persists as a narrow channel communicating between the third ventricle in front, and the fourth ventricle behind, the *iter a tertio ad quartum ventriculum*.

Posterior Cerebral Vesicle.

Divided into an anterior and a posterior part.

From the roof of the anterior part arises the *cerebellum*, from its floor the *pons Varolii*.

The posterior part gives rise to the medulla oblongata.

Its cavity is called the 4th ventricle, continuous with the central canal of the spinal cord. Its upper wall is thinned and forms the *valve of Vieussens*; it communicates with the subarachnoid space through the *foramen of Magendie*.

Fissures and Commissures of the Brain.

The surface of the cerebral hemispheres is at first quite smooth, but as early as the third month the great *Sylvian fissure* begins to be formed.

The *parieto-occipital* appears next.

These two, unlike the rest of the sulci are formed by the curving around of the whole cerebral mass.

The *fissure of Rolando* appears in the 6th month.

From this time on the brain grows rapidly, and the convolutions appear in quick succession.

The *commissures* (anterior, middle, and posterior) and the corpus callosum (*vide supra*) are developed from the growth of fibres across the middle line.

SPECIAL SENSE ORGANS. The Eye.

The *primary optic vesicles* are lateral hollow outgrowths from the anterior cerebral vesicle growing towards the free surface, and communicating with the cavity of the vesicle by the canal in their pedicles.

Each vesicle is soon met and invaginated by an in-growing process from the epiblast.

This process is at first a depression, which ultimately becomes closed in at the edges, so as to produce a hollow ball, completely separated from the epithelium with which it was originally continuous. From this hollow ball is developed the *crystalline lens*.

By the ingrowth of the lens the anterior wall of the primitive optic vesicle is forced back nearly into contact with the posterior, and its cavity almost obliterated. The cells in the anterior wall are much longer than those in the posterior. From the anterior is developed the *retina* proper and from the posterior the *retinal pigment*.

The cup shaped hollow in which the lens is lodged is termed the *secondary optic vesicle*. Its walls grow up all around, leaving however a slit at the lower part (coloboma iridis). Through this slit (choroidal fissure), a process of mesoblast containing numerous blood-vessels projects, and occupies the secondary vesicle, behind the lens, filling it with the *vitreous humor*, and furnishing the *lens capsule*, and *capsulo-pupillary membrane*.

In mammals this process projects further into the pedicle of the primary vesicle, invaginating it for some distance from beneath, and thus carrying up the *arteria centralis retinæ* to its permanent position in the centre of the optic nerve.

The cavity of the primitive optic vesicle becomes completely obliterated. The rods and cones come in contact with the pigment layer, the cavity of the pedicle disappears and the solid optic nerve is formed.

The cavity which existed in the centre of the lens becomes filled up by growth of fibres from its posterior wall.

The epithelium of the *cornea* is developed from the epiblast, while the corneal tissue proper arises from the mesoblast, which intervenes between the epiblast and the primitive lens which was continuous with it.

The *sclerotic* is developed from the general mesoblast in which the eye is embedded.

The *iris* is formed rather late as a circular septum projecting inrds from the fore part of the choroid, between the lens and the cornea.

In mammals the pupil is closed by a delicate membrane (membrana pupillaris), which forms the front part of a highly vascular membrane that, in the fœtus, surrounds the lens (membrana capsulo-pupillaris). It withers and disappears in the human subject a short time before birth.

The **eyelids** are first developed in the form of a ring. They then extend over the globe of the eye until they meet, and become firmly agglutinated to each other. But before birth in man, and after birth in carnivora, they again separate.

The Ear.

Early in the development of the embryo a depression or ingrowth of the epiblast occurs on each side of the head, which deepens and soon becomes a closed follicle, the *primitive otic vesicle.* It soon becomes triangular in shape, base upward. It sinks down some distance from the free surface and from it is developed the epithelial lining of the membranous labyrinth of the internal ear (vestibule, semicircular canals, and scala media of the cochlea).

The mesoblast immediately surrounding the vesicle furnishes the various fibrous, bony, and cartilagenous parts which complete and enclose the membranous labyrinth, (the bony semicircular canals, the walls of the cochlea, with the scala vestibuli, and scala tympani).

The *auditory nerve,* according to some, grows out of the neural tissue of the hind brain, according to others, is differentiated in the mesoblast between the brain and internal ear.

The *Eustachian tube,* the *cavity of the tympanum,* and the *external auditory meatus* are formed in connection with the inner part of the first visceral cleft.

The *ossicles* are developed from the corresponding arch

The *membrana tympani* is formed at the surface of the embryo; the adjacent parts grow outward, and give rise to the external ear.

A diverticulum of the mucous membrane of the mouth is prolonged upward into the Eustachian tube and comes in close relation with the cutaneous surface at the membrana tympani.

The Nose.

Like the eye and ear the nose originates in a depression of the superficial epiblast at each side of the fronto-nasal process (*primary olfactory groove*), which, at first, is completely separated from the cavity of the mouth, but gradually extends backwards and downwards, till it opens into the mouth. The outer angles of the fronto-nasal process, uniting with the maxillary process on each side, convert what was at first a groove into a closed canal.

APPENDIX.

WEIGHTS AND MEASURES.

480.0 grains Troy = 1 oz. Troy.
437.5 " " = 1 oz. Avoirdupois.
1 lb. (12 oz.) = 5760.0 grs. Troy.
1 lb. (16 oz.) = 7000.0 grs. Troy.

1 fluid-ounce ($\frac{1}{20}$ pint)	437.5 grains.
1 pint (⅛ gallon)	8750.0 "
1 imperial gallon of water at 60°	70000.0 "

Measures of Length.

	In English Inches.
Millimetre, (mm), ...	0.039
Centimetre, (cm), ...	0.393
Metre	39.370
Kilometre	0.621 mile

Micro-millimetre, or micron = 0.001 mm.

1 inch.	2.540 centimetres.
1 foot	30.480 "
1 yard	0.914 metre.
1 mile	1.609 kilometre.
$\frac{1}{1000}$ in.	$\frac{1}{40}$ millimetre about.
$\frac{1}{2000}$ in.	12.7 microns.
$\frac{1}{2500}$ in.	10.16 microns.

Measures of Capacity.

	In cubic inches.	In pints.	In U. S. fluid ounces.
Cubic centimetres (c. c.) . .	0.061 . .	0.002 . .	0.034
Litre	61.027 .	1.760 .	33.810

1 cubic inch	16.39 c. c.
1 pint	0.57 litre.
1 gallon	4.54 litres.
1 gallon (U. S.)	3.78 "

Measures of Weight.

	In English grains.	In Avoirdupois lbs. (7000 grs.)
Millegram	0.015	
Centigram	0.154	
Gram	15.432	0.002
Kilogram	15432.349	2.204

1 grain = 0.65 gram.
1 oz. Troy = 31.103 grams.
1 lb. Avoirdupois = 0.45 kilogram.
1 cwt. = 112 lbs. = 50.802 kilograms.

TABLE

OF THE CENTIGRADE AND FAHRENHEIT SCALES OF THE THERMOMETER.

C.	F.		C.	F.	
—25° =	—13°.0		38° =	100°.4	
20	4 .0		39	102 .2	
18	0 .4		40	104 .0	
17	+1 .4		41	105 .8	
10	14 .0		42	107 .6	
5	23 .0		45	113 .0	
1	30 .2		50	122 .0	
0	32 .0	Freezing Point.	55	131 .0	
+1	33 .8		60	140 .0	
5	41 .0		65	149 .0	
10	50 .0		70	158 .0	
15	59 .0		75	167 .0	
20	68 .0		80	176 .0	
25	77 .0		85	185 .0	
30	86 .0		90	194 .0	
35	95 .0		95	203 .0	
36	96 .8		100	212 .0	Boiling Point.
37	98 .6				

One degree F° is equal to $\frac{5}{9}$ of a degree C°; therefore,
To reduce C° to F°, multiply by $\frac{9}{5}$ and add 32°.
To reduce F° to C°, subtract 32° and multiply by $\frac{5}{9}$.

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